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EXPERIMENTAL STUDIES IN ROTE-LEARNING THEORY. I. REMINISCENCE FOLLOWING LEARNING BY MASSED AND BY DISTRIBUTED PRACTICE

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INTRODUCTION

In an investigation designed to test the retention of nonsense-syllable materials over short periods of time, Ward (**28**) found a pronounced initial increase in retention. Recall and relearning scores both indicated greater retention after a two-minute lapse of time than immediately following learning. One explanation for this paradoxical increase in retention with the passage of time ('reminiscence') has been advanced by Hull (**14**) on the basis of a theory containing postulates suggested by conditioned-response experiments. The complete exposition of this approach is reserved for a forthcoming monograph (**16**) but the fundamental logic of it can be briefly summarized. The theory postulates the operation of both

[1] This is the first of a series of studies by the writer and collaborators on the experimental investigation of implications of a mathematico-deductive theory of rote learning to appear in a monograph by Hull, Ross, Perkins, and Hovland (**16**). A preliminary report of the present research was made before the Eastern Branch of the American Psychological Association in 1936 (**6**).

The author expresses his gratitude to Professor Clark L. Hull for encouragement of the research, and to his colleagues Professors A. W. Melton, D. G. Marquis, and R. R. Sears for critical reading of the manuscript.

'excitatory' and 'inhibitory'[2] processes in learning. The number of syllables recalled at a given time is determined by the relative strengths of the excitatory process and the competing inhibitory process. Now if the same principles operate in serial learning which obtain in conditioned-response experiments (Lepley hypothesis, **18**), we should expect that inhibitory tendencies in the early stages of weakening through the lapse of time would diminish more rapidly than would the concurrent excitatory tendencies (**25**, p. 138). This would result in an initial increase in effective excitatory strength with the passage of time, similar in principle to the initial rise in strength of conditioned responses (**7**). Applying this logic to rote-learning experimentation, the deduction would be made that with the lapse of time the number of syllables recalled (determined by the effective excitatory strength) would initially increase. The increase should be most pronounced at the center of the series, where inhibition is assumed to be maximally operative.

The same reasoning may be employed to explain the pronounced efficacy of distributed practice in nonsense-syllable learning (*cf. e.g.* Robinson, **26**). The time between repetitions of the lists, if not too long, would dissipate the inhibitory process more rapidly than the excitatory process (**14**). With a given amount of training the method of distributed practice should, therefore, yield relatively less accumulated inhibition than the method of massed practice. Indirect indication of the validity of this explanation is afforded by experiments of the writer (**11**) which show that distributed practice results in a marked reduction in the difficulty of the central portions of the syllable series, where inhibition should be greatest, but slight reduction in the difficulty of the end syllables.

But the theory would also lead us to expect little reminiscence when the learning has been by distributed practice, since in that case the inhibitory process would be already

[2] The term 'inhibition' is used throughout our system as a *construct*. This *conceptual* usage is to be distinguished from one with intended *neurological* implication (*Cf., e.g.* Pavlov, **25**). Our usage of the term is not inconsistent with an interpretation of 'inhibition' as a competing excitatory process (*Cf.* Guthrie, **5**, or Wendt, **29**).

largely dissipated by the previous rest intervals between trials. The testing of this deduction is the central problem of the present study. Comparison of the amount of reminiscence following massed and distributed practice should permit us to relate the phenomenon of reminiscence to the efficiency of distributed practice (as suggested by Bunch and Magdsick, **2**), and to test the validity of the general proposition demanded by our theoretical system that *as the magnitude of inhibition at the termination of practice decreases, other things being equal, the magnitude of the difference in effective strength of the excitatory tendencies at the termination of learning and at the post-learning maximum will decrease.* Related theorems derived from the same system, such as the proposition that the difference in reminiscence with distributed and massed practice should be most apparent in the central portions of the list, will be discussed in connection with the results incidentally obtained. The effect upon reminiscence of decreasing the inhibitory process by other methods of learning will be described in a later article in this series (**9**).

The present report will follow the usage of Ward in designating this short-time improvement in retention as 'reminiscence' without differentiating it from the type obtained by Ballard (**1**), where increased retention was found at intervals of a day or more. The relationship between these two phenomena is not at all clear at present. The work of Luh (**19**) suggests that the difference between the retention curves obtained by Ebbinghaus and Ballard is probably not due to (1) the degree of learning of the materials, or (2) the method of measuring the retention. According to evidence summarized by McGeoch (**20**), "The factors of age, sex, intelligence, and familiarity of the learning material have not been demonstrated to affect reminiscence (p. 89)."[3] This suggests that differences in the type of learning material may be an important determinant of the temporal course of retention, but no completely satisfactory way of equating the methods of measuring reminiscence with varying materials has yet been proposed. From the standpoint of research on

[3] A study of the effect of age upon the Ward phenomenon will be reported later (**12**).

theoretical problems, however, it is of course apparent that investigation of the Ward phenomenon has important advantages. With short intervals between learning and recall precise laboratory control of the intervening activity is permitted to a degree which is impossible with longer intervals.

Experimental Procedure

The basic method of the experiment was to have subjects learn twelve nonsense syllables by massed and by distributed practice to a criterion of seven syllables correct. The subjects then continued the learning by massed practice to one perfect recitation either immediately or following a two-minute pause. Retention with and without the two-minute pause could then be compared for massed and distributed practice. The reminiscence effect was studied following the criterion of seven syllables correct because with this degree of partial learning one avoids the possibility of having to deal with the unmeasurable extremes of all syllables correct or none correct.

Each subject learned the lists on any given day according to one of the following four programs:

I. *Learning to one perfect recitation by massed practice.* Here there was no interruption of the learning by massed practice until mastery was attained.

II. *Learning to the criterion of seven syllables correct by massed practice, introduction of rest pause, continuation of learning by massed practice to one perfect recitation.* Subjects learned the lists by massed practice. Immediately following the first trial on which seven or more syllables were correctly anticipated, the shutter at the window where the syllables were exposed was closed and the shutter exposing the colors was opened. Following two minutes of color-naming, this shutter was again closed, and the syllable shutter reopened. The subjects then continued the learning by massed practice until mastery.

III. *Learning to criterion of seven syllables correct by distributed practice, remainder of learning without pause to one perfect recitation by massed practice.* Here the subjects learned to a criterion of seven syllables correct by distributed practice in which recitation and color-naming were alternated. Following the first trial on which seven or more syllables were correctly anticipated, the color-naming was discontinued and the remainder of learning continued by massed practice.

IV. *Learning to criterion of seven syllables correct by distributed practice, introduction of rest pause, remainder of learning to one perfect recitation by massed practice.* This was identical with Program III except for the fact that an additional period of color-naming was introduced after the criterion trial and before the continuation by massed practice.

To obtain data to verify Ward's results on the reminiscence effect following complete learning, the cases involving the first program were subdivided, half of them continuing to a second perfect recitation immediately, the others after a two-minute period of color-naming. Data on the effect of one presentation of the list were obtained by comparing the first trials in Programs I and II with those of Programs III and IV. The only respect in which these cases differed was in whether or not the first recall trial followed the initial presentation of the list immediately or after a two-minute rest pause.

The syllables were learned in serial order by the anticipation method with conditions previously described (15). The syllables were printed in 18-point black capitals on heavy paper. The individual syllables were then mounted on a continuous band.

Colored papers were mounted in a series and were presented during the rest pause at the same rate and in the same way as the syllables. The syllables were exposed through a window 1 inch by 1.1 inches. They were brightly illuminated without glare by a light behind the subject. The syllables as presented could be seen by the experimenter by means of a mirror arrangement. The experimenter was completely cut off from the view of the subject by a large screen six feet high and four feet wide. The experiments were conducted in a sound-proof chamber to eliminate distracting noises. The syllables were presented at two-second intervals. Between successive presentations of the list there was a six-second pause in the case of massed practice, and a two-minute six-second pause in the case of distributed practice. Detailed records of all responses were kept on mimeographed forms.

The subjects were thirty-two college students, who were paid for their services. They had never previously been employed in memory experimentation, and did not know the purpose of the experiment. The schedule was so arranged that the subjects reported at the same time every day except Sunday. Each subject served twenty-two days in all, during which time six practice sessions and four cycles of the experimental programs were completed. During the practice periods each type of procedure was employed. A sample program for one subject would be the following:

Day

I. Learning of list by massed practice throughout.
II. Learning of list by distributed practice throughout.
III. Program II.
IV. Program IV.
V. Program I.
VI. Program III.

The program for the first two days was the same for all subjects, except that half learned by distributed practice first, while the other half learned first by massed practice.

The instructions given at the beginning of the investigation were similar to those used in other experiments in this laboratory:

> "This is an experiment in learning a list of nonsense syllables, and not a psychological test. We are interested in certain complex relationships of the learning process common to all people, and not concerned with your personal reactions.
>
> "Shortly after the apparatus starts you will see a three-letter syllable in the window. You are to pronounce this syllable and those that follow it as you see them. After you have seen the list once, you are to endeavor to anticipate the syllables; in other words, as you see one syllable you are to pronounce the syllable that will follow it *before* it appears. If you think you know what a syllable will be, but are not sure, guess, because it will not hurt your score any more than to say nothing, and if you get it right it will count as a success. If you anticipate a syllable incorrectly, correct yourself as soon as it appears. Try always to speak the syllables as distinctly as possible.
>
> "Please do not try to think ahead more than one step at a time, or to count, or to make up fanciful connections between the syllables to assist the learning process. Don't try to use any special system in your learning; simply associate each syllable with the next one as the series moves along. When the shutter goes down, begin naming the colors as they are presented. Do not ask questions about the purpose of the study until the experiment is over."

Sixteen experimental and six practice bands were prepared. The lists were twelve syllables long with a cue symbol. They were made up according to the method described by Hull (15) in such a way that each band contained syllables having the same mean and average deviation in association value. Successive pairs of syllables had approximately the same sums of association frequency, as determined by Hull (13). The syllables were systematically rotated so that each pair of syllables would appear in every possible place in the series when the subjects were taken as a group. The rules formulated by Müller and Schumann (23) were observed. Counterbalanced practice equilibration was employed (Robinson, 27). Each subject began with a different list, and each type of program was represented equally in each position of practice during learning.

Results

Verification of reminiscence effect with controlled rest period. —In Ward's main experiment the subjects rested and read jokes during the rest period. This activity could not be controlled sufficiently to make rehearsal impossible. In the present experiment color-naming was therefore introduced during the rest period, an activity which does effectively prevent rehearsal, but causes little retroactive inhibition (21). Ward, in a supplementary experiment, had some of his subjects give color-associations during the rest interval, and the results indicated that reminiscence was actually greater when color-associations were given than when rest was interpolated.

The results obtained in the present experiment with recall immediately after one presentation of the list and with recall after a two-minute period of color-naming are given in Table 1. The number of syllables correctly recalled is reliably higher when two minutes elapse between presentation and recall than on the control tests when recall is immediately after learning ($C.R._{P.E.} = 6.34$). These results are in complete confirmation of those of Ward.

McGeoch (20) has stressed the value of presenting ordinary reminiscence data in terms of number of subjects showing improvement. The results of the present experiment are expressed in this form in Table 1-*B*. Trials representing the same practice level with and without the two-minute rest pause were paired for each cycle. Comparisons were then made between the two members of these pairs. The trials in which no rest pause was given were superior in less than

TABLE 1

RETENTION FOLLOWING ONE PRESENTATION OF NONSENSE SYLLABLE SERIES WITH AND WITHOUT 2-MINUTE REST PAUSE BETWEEN PRESENTATION AND RECALL

(A) Recall Scores

(32 subjects, 4 determinations for each condition)

	Mean	P.E.M
No. syllables correctly recalled immediately after presentation	1.183	0.053
No. syllables correctly recalled 2 minutes after presentation	1.570	0.095
Difference	.387	
$P.E._{diff.}$*	.061	
Critical ratio	6.34	

(B) Cases and Subjects Showing Reminiscence

(128 paired cases)

	Per cent	P.E.P
Paired trials in which more syllables were recalled following 2-minute period than immediately	46.9	.030
Paired trials in which same number of syllables were recalled	30.5	.028
Paired trials in which fewer syllables were recalled	22.6	.026

(32 subjects)

1. Subjects who recalled more syllables following 2-minute pause than immediately	56.3	.059
2. Subjects who recalled the same number	31.2	.055
3. Subjects who recalled fewer	12.5	.039

* The formula for the $P.E._{diff.}$ which involves the correlation of the two sets of data was employed where permissible. These $P.E._{diff.}$ will be indicated by an asterisk (*). The correlations were obtained after pooling the determinations for each subject, thus eliminating practice effects during the four cycles.

twenty-three per cent of these comparisons. Only twelve and a half per cent of the subjects remembered more syllables when testing was immediately after presentation of the list than they did when a two-minute rest period was interpolated.

In Table 2 the recall and relearning scores are given to indicate the reminiscence following the first perfect recitation. It will be observed that both with and without the rest pause there is a loss on the trial following the one on which twelve syllables were correctly anticipated. This loss has already been adequately explained by Ward (**28**). Trial-by-trial records for individual subjects show alternation of improvement and decrement throughout learning. Ward has shown that when we select the first trial on which a given number of syllables are recalled, we are taking the peak of a fluctuating series, and the next trial will therefore tend to show a loss, especially in the advanced stages of learning where the rate

TABLE 2

RETENTION FOLLOWING FIRST PERFECT RECITATION TRIAL WITH LEARNING BY MASSED PRACTICE WITH AND WITHOUT 2-MINUTE REST PAUSE BETWEEN LEARNING AND RELEARNING

32 subjects. 2 determinations for each condition

RECALL	Mean	P.E.M	RELEARNING	Mean	P.E.M
No. syllables correctly recalled immediately after first perfect recitation trial	11.12	0.059	No. trials to relearn to mastery without rest pause following first perfect recitation †	0.88	0.058
No. syllables correctly recalled 2 minutes after first perfect recitation trial	11.49	0.049	No. trials to relearn to mastery with 2-minute rest pause after first perfect recitation	0.62	0.057
Difference 0.37			Difference 0.26		
P.E.diff.* 0.056			P.E.diff.* 0.057		
Critical Ratio 6.61			Critical Ratio 4.56		
	Per cent	P.E.P		Per cent	P.E.P
Paired trials in which more syllables were recalled following 2-minute period than immediately	41.4	.042	Paired trials in which fewer relearning trials were required following 2-minute period than immediately	38.3	.041
Paired trials in which same number were recalled	37.5	.041	Paired trials in which same number were required	42.2	.042
Paired trials in which fewer were recalled	21.1	.034	Paired trials in which fewer were required	19.5	.034
1. Subjects who recalled more syllables following 2-minute pause than immediately	46.9	.059	1. Subjects who required fewer relearning trials following 2-minute pause than immediately	55.0	.059
2. Subjects who recalled the same number	40.6	.059	2. Subjects who required same number	37.2	.057
3. Subjects who recalled fewer	12.5	.040	3. Subjects who required more	7.8	.032

† In computing number of trials required for relearning, the final criterion trials are omitted throughout the paper.

of improvement is negatively accelerated. All of the indices of reminiscence employed show reliably greater retention following the two-minute interval. Only 8 per cent of the subjects relearned to the criterion of mastery in fewer trials immediately after learning than following the rest pause.

Decrease in Inhibition Following Distributed Practice.— With a given amount of training the method of distributed practice should, theoretically, yield relatively less accumulated inhibition than the method of massed practice. Since

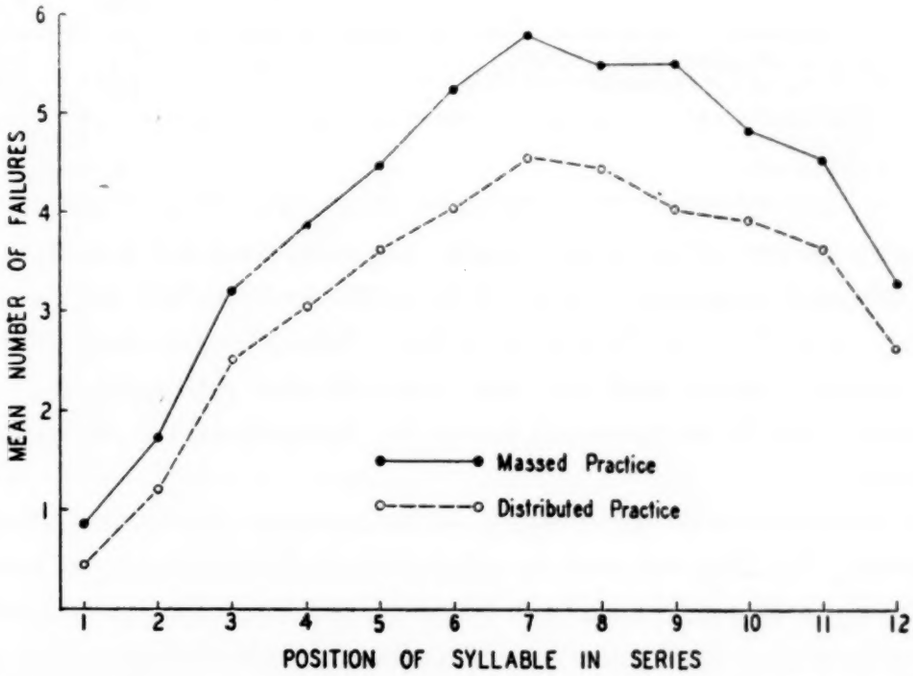

FIG. 1. Composite graphs showing the relative mean difficulty in learning to criterion of 7 syllables correct by massed and by distributed practice. Each point based upon the mean of 256 learning scores.

the number of trials required to learn individual syllables reflects the amount of inhibition present, we can test this expectation indirectly by plotting the number of trials required to learn syllables in each position of the series. When inhibition is decreased the ratio of the number of errors in the central portion of the list to the number at the extremes should decrease. In Figure 1 a graph is presented which shows the mean number of failures for each syllable position in learning to the criterion of seven out of twelve syllables correct. As predicted, the greatest advantage, measured in

absolute improvement, of the distributed practice is manifested in the central portion of the lists, where inhibition is theoretically greatest.

The efficiency of distributed practice over massed, even in learning to such a low criterion as seven out of twelve syllables correct, is indicated in the results shown in Table 3.

TABLE 3

NUMBER OF TRIALS REQUIRED TO LEARN SERIES TO CRITERION OF 7 SYLLABLES CORRECT BY MASSED AND BY DISTRIBUTED PRACTICE

	Mean	P.E.$_M$
No. trials to learn by massed practice	6.13	0.127
No. trials to learn by distributed practice	4.92	0.123
Difference	1.21	
P.E.$_{diff.}$*	0.124	
Critical ratio	9.76	

About 20 per cent fewer trials are required for learning by distributed practice. The difference in number of trials is highly reliable (C.R.$_{P.E.}$ = 9.76). Eighty-one per cent of the paired cases and 94 per cent of the subjects required as many trials or more to learn by massed as by distributed practice.

Comparison of Amount of Reminiscence Following Partial Learning by Massed and by Distributed Practice.—The results concerning the principal problem of the present investigation are presented in Table 4. Recall and relearning scores are given following learning by massed and by distributed practice to the criterion of seven out of twelve syllables correct with and without the two-minute pause. The number of syllables on the criterion trial had been almost exactly the same for the four groups:

Procedure	No. Syllables Correctly Anticipated on Criterion Trial
I. Massed practice, no rest	7.39
II. Massed practice, rest pause	7.43
III. Distributed practice, no rest	7.61
IV. Distributed practice, rest pause	7.59

It is apparent that in some cases the first trial showing the requisite number of syllables correct had over seven correct.

The more rapid learning by distributed practice explains the fact that the scores on the criterion trial are somewhat higher following distributed practice than following massed.

Recall scores are higher ($C.R._{P.E.} = 3.25$) following the rest pause when the learning has been by massed practice, but not when it has been by distributed practice ($C.R._{P.E.} = 0.20$). More subjects show increased retention following the rest pause with massed than with distributed practice. The difference is not completely statistically reliable.

Reminiscence, as measured by the number of trials required to relearn to the criterion score (since here, too, there is a loss following the arbitrarily selected criterion trial), is slightly greater following massed practice than following distributed.

In Table 4-*C*, data are presented to indicate the number of trials required to go from the stage of seven correct anticipations to all twelve syllables correct following massed and distributed practice with and without the two-minute period of color-naming. Reminiscence is present following both massed and distributed practice, but is statistically reliable only following the massed practice. There is a reliable difference in the amount of reminiscence, as judged by the number of trials required to go from the criterion of seven correct to mastery, following massed and distributed practice. Seventy-five per cent of the subjects require the same number or fewer trials to learn to mastery from seven syllables correct with the two-minute pause, than without, while the corresponding figure following distributed practice is 62 per cent.

Figure 2 presents the data graphically. Here the number of trials required to reach successive criteria are plotted for the massed practice series with and without the rest pause following the attainment of the criterion of seven syllables correct. This method is similar to the one employed by Melton (**22**). If the same number of recitations were required to go from one syllable correct to two correct, from two correct to three correct, etc., the function would appear linear. However, the curve obtained with massed practice throughout shows the typical pronounced negative accelera-

TABLE 4

RETENTION WITH AND WITHOUT 2-MINUTE REST PAUSE FOLLOWING LEARNING TO CRITERION OF 7 OUT OF 12 SYLLABLES CORRECT BY MASSED AND BY DISTRIBUTED PRACTICE.

32 subjects; 4 determinations upon each

(A) RECALL	Massed Practice		Distributed Practice	
	Mean	P.E.$_M$	Mean	P.E.$_M$
Syll. recalled, no rest pause after crit. trial	6.96	.122	8.00	.153
Syll. recalled, 2-min. rest pause after crit. trial	7.49	.128	8.04	.132
Difference	0.53		0.04	
P.E.$_{diff.}$*	0.163		0.191	
Critical Ratio P.E.	3.25		0.20	
	Per cent	P.E.$_P$	Per cent	P.E.$_P$
Paired trials with more syll. recalled following 2-min. period than immed.	46.9	.030	44.5	.030
Paired trials, same number recalled	19.5	.024	16.4	.022
Paired trials, fewer recalled	33.6	.028	39.1	.030
1. Subjects recalling more syll. following 2-min. pause than immed.	50.0	.059	43.8	.059
2. Subjects recalling same number	18.8	.046	25.0	.052
3. Subjects recalling fewer	31.2	.055	31.2	.055
(B) RELEARNING TO 7 CORRECT	Mean	P.E.$_M$	Mean	P.E.$_M$
Trials required to relearn to 7 correct, no rest pause after crit. trial	0.53	.064	0.19	.048
Trials required to relearn to 7 correct, 2-min. rest pause after crit. trial	0.33	.089	0.19	.051
Difference	0.20		—	
P.E.$_{diff.}$*	.099		.064	
Critical Ratio P.E.	2.02		—	
(C) TRIALS REQUIRED TO PROCEED FROM 7 CORRECT TO MASTERY	Mean	P.E.$_M$	Mean	P.E.$_M$
Trials required to learn to mastery from 7 syll., no rest pause after crit. trial	9.79	.461	6.66	.269
Trials required to learn to mastery from 7 syll., 2-min. rest pause after crit. trial	6.94	.233	6.01	.336
Difference	2.85		0.65	
P.E.$_{diff.}$*	.372		.289	
Critical Ratio P.E.	7.66		2.25	
Critical Ratio P.E. of Difference between improvement by Massed and by Distributed Practice	4.68			
	Per cent	P.E.$_P$	Per cent	P.E.$_P$
Paired trials requiring fewer trials to learn to mastery following 2-min. period than immed.	59.4	.030	53.1	.030
Paired trials, same number required	12.5	.020	9.4	.018
Paired trials, more required	28.1	.027	37.5	.029
1. Subjects requiring fewer trials to learn to mastery following 2-min. pause than immed.	68.8	.055	50.0	.059
2. Subjects requiring same number	6.3	.028	12.5	.040
3. Subjects requiring more	24.9	.052	37.5	.057

tion in the later stages of learning. Comparison of the two curves (with and without the rest pause after the criterion trial of seven syllables correct) shows very slight divergence up to the point of seven correct anticipations. Up to this point the procedure has been identical for the two groups. The introduction of the two-minute period of color-naming results in an acceleration of learning. This method of plotting the reminiscence effect does not, however, permit analytical examination of the improvement. Is the effect

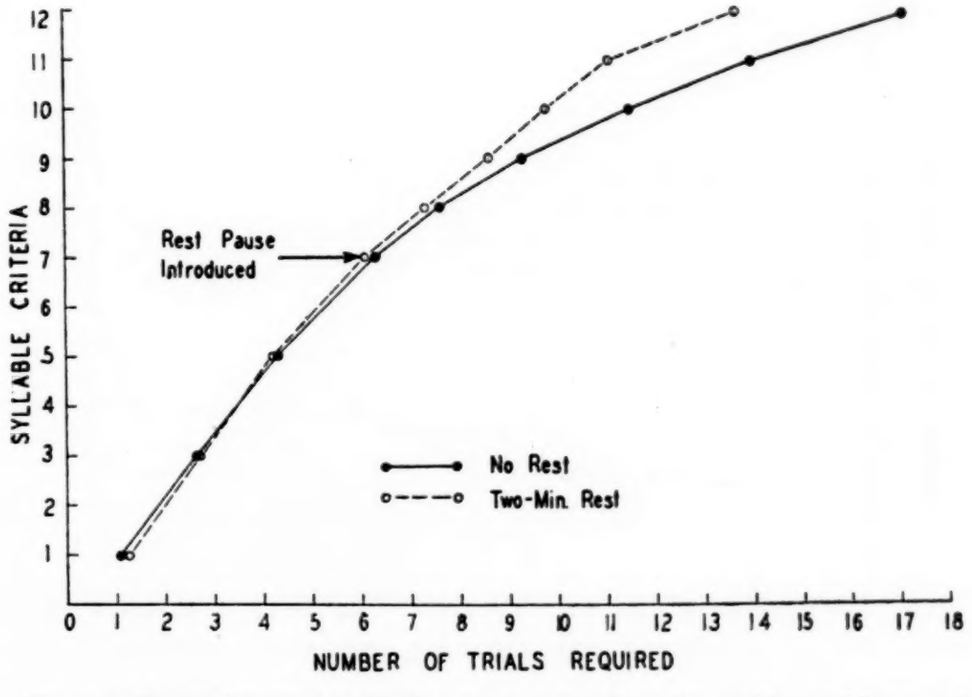

FIG. 2. Composite curves showing average number of repetitions of list required to anticipate correctly varying numbers of syllables with and without the rest pause introduced after 7 syllables were learned by *massed practice*. Each point based upon the mean of 128 learning scores.

restricted to making achievement of the next syllable less difficult, or does it extend to making easier the attainment of criteria several syllables beyond? Indirect answer to this question was sought by computing the data in terms of the number of trials necessary to go from one criterion of learning to the next throughout the series. The curve for the series learned without pause indicates very clearly the trend already mentioned; *i.e.*, the attainment of the later syllables in the learning is disproportionately difficult. The introduction of

the rest pause appears to decrease temporarily this accumulation of difficulty, making easier the attainment of additional syllables (Fig. 3).

Figure 4 presents results for distributed practice comparable to those of Fig. 2. The amount of reminiscence is scarcely visible.

It will be observed that only one time-interval following learning has been employed in testing the theoretical deduction. It is possible that some different time-interval

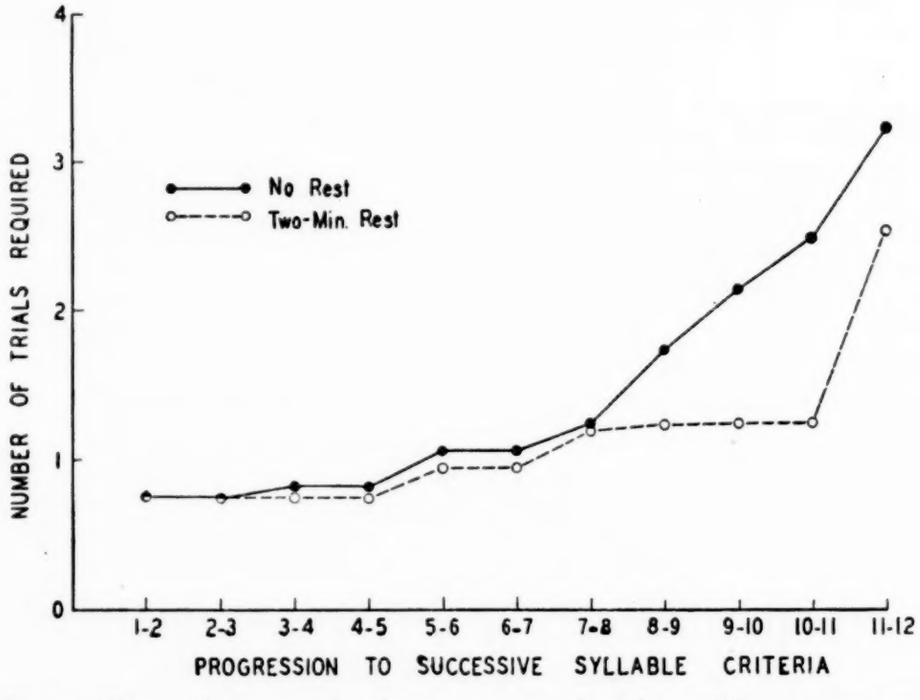

FIG. 3. Composite curves showing average number of repetitions to progress from one criterion of performance to next when learning is by massed practice with and without rest pause after 7 syllables correct.

would be more favorable for the appearance of reminiscence with distributed practice. Our theoretical system permits specific prediction of such changes and the results of experiments designed to test these deductions will be published soon (**10**). At no subsequent interval was a greater reminiscence shown with the learning by distributed practice.

Relative Amount of Reminiscence in Central and End Positions of the Series.—The effect of the rest pause may be seen quite dramatically when the number of failures at each syllable position made on the trials between the attainment

of seven correct and mastery are plotted for the trials learned with and without the two-minute rest pause following massed practice (Fig. 5). As predicted by the theory, decrease in the number of errors with distributed practice is most marked in the central portion of the list. This confirms a similar finding by Ward (**28**). The ratio of the number of failures in the central positions of the curve (syllables 6 and 7) to the number at the extremes (syllables 1 and 12) is 9.75 without the rest period, but only 6.80 with the pause. No significant

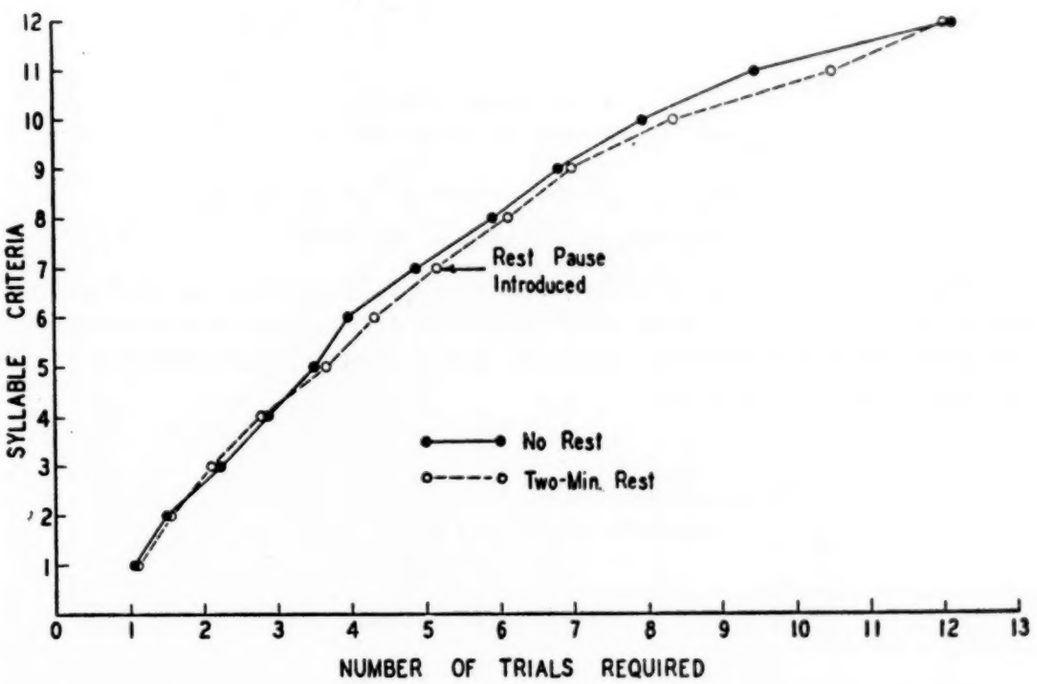

FIG. 4. Composite curves showing average number of repetitions required to anticipate varying number of syllables with and without rest pause after 7 syllables correct when learning has been by *distributed* practice. Each point based upon the mean of 128 learning scores.

change in the curve of errors is made by the introduction of the two-minute rest pause when the learning has been by distributed practice (Fig. 6). The number of errors made in each syllable position on the recall trial shows the same effect but much less markedly (Table 5).

In connection with his finding that reminiscence is greatest in the central portions and least at the ends, Ward has pointed out the difficulty of isolating the serial position effects from the effects of concomitant variations in the degree

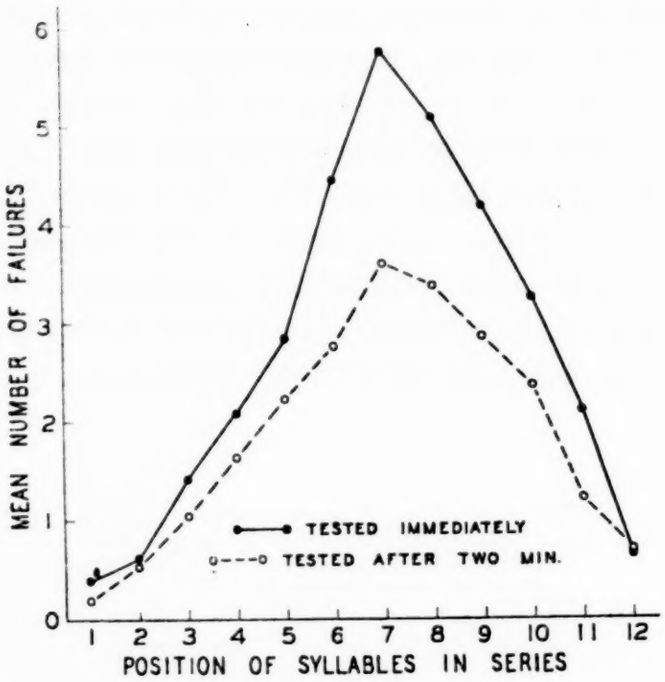

FIG. 5. Mean number of failures in various syllable positions on trials between the one on which 7 and the one on which 12 syllables were anticipated with and without rest pause following learning to 7 correct by *massed practice*. Each point based upon the mean of 128 learning scores.

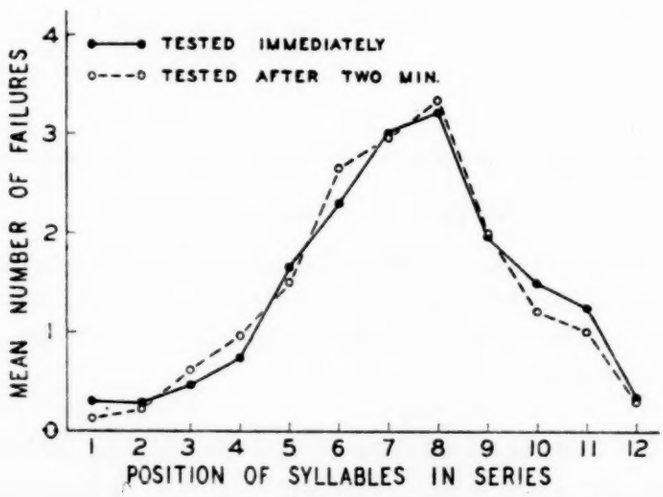

FIG. 6. Mean number of failures in various syllable positions on trials between the one on which 7 and the one on which 12 syllables were anticipated with and without rest pause following learning to 7 correct by *distributed practice*. Each point based upon the mean of 128 learning scores.

of learning. He uses this fact as an argument against an explanation of reminiscence based upon dissipation of inhibitory effects in the central portions of the list. The present

TABLE 5

MEAN NUMBER OF ERRORS IN EACH SYLLABLE POSITION ON RECALL TRIAL WITH AND WITHOUT REST PAUSE WHEN LEARNING HAS BEEN TO CRITERION OF 7 OUT OF 12 SYLLABLES CORRECT BY MASSED AND BY DISTRIBUTED PRACTICE

Positions in Series		1	2	3	4	5	6	7	8	9	10	11	12
MASSED PRACTICE													
Mean No. Errors	Recall immediately	0.000	0.031	0.203	0.281	0.375	0.610	0.688	0.672	0.765	0.562	0.312	0.219
	Recall after 2 min.	0.016	0.063	0.188	0.234	0.406	0.563	0.671	0.563	0.640	0.532	0.360	0.188
DISTRIBUTED PRACTICE													
Mean No. Errors	Recall immediately	0.016	0.031	0.156	0.422	0.453	0.515	0.625	0.640	0.422	0.250	0.266	0.140
	Recall after 2 min.	0.016	0.031	0.156	0.141	0.328	0.531	0.610	0.735	0.515	0.437	0.282	0.140

experiments afford one means of separating these two effects. The syllables in the central portion of the lists learned by massed practice represented, in terms of the criterion of recall score, the same degree of learning as did those in the lists learned by distributed practice. One series, however, showed much more reminiscence than the other. This type of evidence tends to suggest that degree of learning, *per se*, is not the fundamental factor determining reminiscence, although it is probably closely related to it.

Distributed Practice and Jost's Law.—It will be observed that both recall and relearning scores indicate better retention after distributed practice than following massed practice (Table 4). Without a rest pause 6.96 syllables are remembered after massed practice, 8.00 after distributed. This difference is statistically reliable. Similarly, 9.79 trials are required to learn to mastery from seven syllables correct following massed practice without a pause, but only 6.66 under the same conditions after distributed practice. Since distribution of practice increases the average age of the associations learned, these results are in confirmation of Jost's first law which states that when two associations are of the same strength but of unequal age, a new repetition increases the strength of the older more than that of the younger association.[4]

Discussion

A large number of theories have been advanced to explain reminiscence phenomena. The principal ones seek to explain reminiscence on the basis of one of the following factors: (1) Rehearsal; (2) Fatigue; (3) Motivation; (4) Perseveration; (5) Removal of inhibition.

Rehearsal may be a factor in ordinary reminiscence experiments where recall is tested after intervals of several

[4] "Sind zwei Assoziationen von gleicher Stärke, aber verschiedenem Alter, so hat für die ältere eine Neuwiederholung grösseren Wert" (17, p. 472). Discussion of the derivation of this result from our theoretical system is reserved for a later article. A discussion of the implications of Jost's law for our theory will be found in the Ph.D. dissertation of Adella C. Youtz, entitled 'Functional Equivalence at Comparable Points in Learning and Forgetting: An Experimental Evaluation of Jost's Law,' Yale University Library, 1937.

days, although there is some evidence to the contrary presented by Ballard (1) and by McGeoch (20). But in our experiment, the color-naming during the rest pause prevented any rehearsal of the material, and reminiscence still appeared. Moreover, rehearsal even if present would not explain the difference in the amount of reminiscence following massed and distributed practice.

Fatigue has also been discussed as an explanation for reminiscence. "If the preceding practice of a habit be carried to a point of some fatigue, the rate of learning will be likely to be impeded, and may be released from the impediment only after a rest interval." (Dashiell, 3, p. 367.) From this it would be predicted that fatigue would accumulate more rapidly during massed practice than during distributed, and hence a rest pause would be more effective after massed practice. Consequently, reminiscence should be greater following massed than following distributed practice. Experimentally, these were the results obtained. Now fatigue may be given a psychological definition so as to be practically synonymous with 'inhibition' in learning. Such a usage would explain many of the results of learning experiments currently attributed to 'inhibition.' But such a theory would not then be parsimonious, since it would fail to account for many of the phenomena, such as serial position effects, which an inhibitory theory will explain without additional postulates. If, on the other hand, 'fatigue' is restricted to 'physical fatigue,' a number of objections can be raised to fatigue as an explanation of reminiscence results. Ballard (1), for example, was unable to detect the alleged fatigue by any independent tests. In his situation he also found that a prolonged night's rest, which removed all feeling of fatigue, failed to prevent reminiscence. Further evidence against the fatigue theory is provided by the experiments of Jost (17) on distributed practice. Good evidence against a fatigue explanation is afforded by the present results, as well as those of Ward, which show pronounced reminiscence after a single presentation of the list, when little fatigue would be expected. Comparison of the amount of reminiscence at various stages

of the learning process would constitute a further check on this explanation, but as already mentioned the problem of measurement in comparable units at various stages of practice has not yet been solved.

Closely allied to this explanation is one based upon *motivation* and emotional habits. "Long-continued practice tends to produce a loss in interest, even a 'staleness,' which is difficult or impossible for the most conscientious of learners wholly to avoid. Certain other emotional attitudes such as worry and impatience, may become set up. A vacation serves to allow an individual's emotional reactions to change in character, so that a renewal of practice later will be supported by a heightened morale" (Dashiell, **3**, p. 367). The same points made in objection to fatigue may be made against this theory, especially the appearance of reminiscence after a single presentation of the material. More specific application of this approach is found when reminiscence is explained as an improvement in performance resulting from a change in the rhythm of work. This would account for the improvement after the introduction of a rest pause following massed practice. But it would also be predicted that after distributed practice the immediate recall (Program III) would be superior to the recall with the customary rest pause (Program IV). This prediction is not in accord with the results obtained.

The results of Geyer (**4**) involving the concept of 'set' would lead to an antithetical prediction. He showed that when individuals are required to recall either earlier or later than they expected there is a decrement in performance. Applied to our experiment, this formulation would predict that there would be less material recalled in Program III, when the normal rest pause between recitations was omitted following the criterion of partial learning, than in Program IV, where the customary rest pause was maintained. This predicted decrease in amount recalled was not obtained.[5]

[5] During the early stages of learning the color-naming has a disruptive effect on recall, but with further practice this effect disappears.

Müller and Pilzecker's (**24**) theory of *perseveration* has been evoked to account for the reminiscence effect. According to this systematization some time is required for a 'setting-in' process following learning. Recall is therefore better following the passage of time. The color-naming activity which we employed would be expected to disrupt such a setting-in process, but reminiscence nevertheless occurs. In addition, an *ad hoc* proposition to the effect that this setting-in process becomes less marked as learning proceeds would be required to explain the absence of reminiscence following distributed practice. A theory similar to this is nevertheless the one favored by Ballard in explaining his results:

"The alternative theory of neural growth, or of some positive brain change, seems more in accordance with the facts of the case. It assumes that an actual modification of brain structure, of the same nature as that which is supposed to occur during learning, gradually goes on during the interval between the tests.

"Reminiscence may be said to be due to the inertia of the nervous system which does not yield to an influence at once. . . . While it is admitted that many of the facts seem to fit in with either the theory of inhibition or the theory of neural growth, it seems to the writer that the latter is the only theory that adequately explains the whole of the phenomena with which we have been dealing." (**1**, p. 82.)

Removal of inhibition with the passage of time has been discussed in the introduction as a systematic explanation of reminiscence. The exact nature of this inhibition is still undetermined, but as a part of a conceptual system it is a useful construct. This interpretation of reminiscence is fundamentally the one arrived at by Ward:

"Whether or no the Lepley hypothesis in either of its dual aspects is finally substantiated, the explanation of Reminiscence in terms of the dying out of a positive interfering tendency growing up during learning is a good one. It is pretty well agreed that what we can call 'inhibitions' in the conceptual sense, without implying anything as to their nature other than a tendency away from the reactions under consideration, are set up during the course of learning.

"Speaking in everyday terms, there is an interaction of attempts not to make incorrect responses and attempts to respond correctly. Often certain new and incorrect responses are partially learned also. It seems natural in the same everyday terms to expect that a short rest from the activity involved should allow one to 'forget' these mistakes which are not as well learned as the correct responses with which they have partially interfered. In terms of such concepts as those of associative and retroactive and proactive inhibition, the interval of rest allows the dying out of these inhibitions which are assumed to have a more rapid rate of disintegration than do some of the positive excitatory tendencies formed at the same time." (**28**, pp. 102–3.)

The predictions based upon this formulation have been supported in the present experiments. Further discussion of this system is reserved for later articles in the series.

Summary and Conclusions

1. Thirty-two subjects learned sixteen lists of twelve nonsense syllables by massed and by distributed practice with and without a two-minute rest period between learning and relearning. Learning was by the serial anticipation method. During the rest pause between learning and testing and between successive trials during distributed practice, the subjects named colors.

2. The reminiscence phenomenon obtained by Ward (**28**) was verified at three stages of learning under controlled conditions in which rehearsal during the rest pause was precluded. There is a statistically reliable increase ($C.R._{P.E.} = 6.34$) in recall following the rest interval *after one presentation of the list*, as compared with control trials on which recall was immediately after presentation. A reliably greater percentage of the subjects recalled more after the rest pause than immediately after learning. Reminiscence was likewise obtained *following the first perfect recitation* with learning by massed practice. Both recall and relearning scores were reliably higher following the two-minute pause. Ninety-two per cent of the subjects required the same number or fewer trials to relearn to mastery following the rest pause.

3. Distributed practice resulted in a significant decrease ($C.R._{P.E.} = 9.76$) in number of trials to learn to the criterion of seven out of twelve syllables correct. Twenty per cent fewer trials were required. The advantage of distributed practice was obviously most marked in the central portion of the syllable series and least at the extremes.

4. Pronounced reminiscence was obtained following learning by massed practice to a criterion of seven out of twelve syllables correct. Recall showed the effect less than did the number of trials required to go from seven syllables correct to mastery. The amount of reminiscence judged by the latter criterion is significantly smaller ($C.R._{P.E.} = 4.68$) following distributed practice than following massed.

5. When the number of failures on the trials between the criterion of seven correct and mastery are plotted for the various syllable positions, the effect of the rest pause is seen most clearly. The curve of errors is markedly flattened following the two-minute period with massed practice, but little change is observed following distributed practice.

6. The rest pause is effective not only in improving recall, but results in improvement in relearning for a considerable time afterward. The rate of negative acceleration in learning is temporarily reduced following the introduction of the rest pause.

7. The fact that recall and relearning are better following distributed practice, even if the reminiscence effect is not shown, is in support of Jost's first law.

8. The advantage for theoretical analysis of studying reminiscence at short intervals over that at long intervals, such as were employed by Ballard, is pointed out. In the former, much more precise laboratory control of the rest-period interval can be introduced.

9. The present experiments afford a method of isolating serial position effects from degree of learning. These results show that when the central portions of two lists are equally well learned, in terms of the criterion of recall, one learned by massed practice will show pronounced reminiscence, while one learned by distributed practice will show little improvement.

10. Theories based upon 1. Rehearsal, 2. Fatigue, 3. Motivation, 4. Perseveration, and 5. Removal of Inhibition are discussed and criticized. It appears to the writer that the last-named theory will most adequately explain all of the results obtained.

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THE INTERRELATIONS OF TWO MEASURES OF CONDITIONING IN MAN *

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In his volume on 'Conditioned Reflexes' (7), Pavlov reported that the experimental animals studied in his laboratory could be classified into four general types. These divisions were based on the differences among the animals in their reactions to the conditioning procedure. He later (8) reduced these categories to three types, excitatory, inhibitory, and central. Novikova (as reviewed by Razran (9)) from a study of positive and negative conditioned grasping responses found that the children comprising his experimental group were of four types, excitable or inhibitable, labile or inert, in their formation of positive and negative conditioned responses. In a more recent study of conditioned salivation in human adults Razran (10) identified three types of subjects, positive, negative, and indifferent. These studies suggest that individuals, human or animal, fall into distinct groups when compared on the basis of their relative reactivity to a conditioning influence.

Experimental findings in psychology have in most cases been unfriendly to theories of psychological types. Studies of honesty, motor skill, introversion, and other traits have produced two common conclusions, first, individual differences in psychological traits are not distributed in bi-modal or multi-modal form but in conformity to the so-called normal probability curve, and second, psychological traits are not general but are strictly specific to each experimental situation.

Despite Pavlov's findings there are strong indications that the first of these conclusions applies to ease of conditioning. Several recent studies have failed to find the conditioning

* This investigation was carried out in the Laboratory of Psychology of Stanford University. The writer wishes to thank Dr. E. R. Hilgard for his assistance and advice.

types which Pavlov and his followers describe. Distributions of individual differences in response to conditioning of the eyelid reflex (1) (2), patellar reflex (12) (13), galvanic skin response (3), and finger withdrawal from shock (14) have been either normal or skewed but in no case have they been clearly bi-modal.

This lack of bi-modality suggests that the trait, ease of conditioning, is not general but relatively specific to each conditioning situation. Data pertinent to this question are not at present available. No comparisons have been drawn between the scores of the same subjects on different measures of ease of conditioning. Pavlov's experimental setups included many different conditioned stimuli but the response to be conditioned was in every case salivation. Apparently within the limits of these 'homogeneous' conditioned responses Pavlov's experimental animals demonstrated marked consistency in their reactions. However, it cannot be inferred from this finding that the same consistency would be present in the conditioning of different reflexes.

The present study was undertaken to discover to what degree ease of conditioning may be considered a consistent trait predictable in the formation of different 'heterogeneous' conditioned responses. The analysis presented herein is limited to the investigation of only two reflexes so that the conclusions to be reached, while pertinent to the problem, must of necessity be tentative.

Procedure

While many human reflexes have been successfully conditioned in the laboratory only a few have been used to demonstrate differences between individuals in the ease with which conditioning may be established. The most satisfactory response from the point of view of this type of research has been the eyelid reflex which conditions readily in most subjects and is easily measured. Distributions have also been obtained from conditioning of the patellar reflex although this reflex is much less susceptible to conditioned modification. These two reflexes were selected to serve as the basis of the conditioning to be studied in the present experiment.

The Conditioned Eyelid Responses

The procedure and apparatus used in the stimulation and recording of the eyelid responses were identical in all important respects with those described in detail by Hilgard and Campbell (4). The conditioned stimulus was an abrupt brightening of a white glass fixation field toward which the subject's eyes were directed. The uncondi-

tioned stimulus was a sharp blast of air delivered onto the cornea of the subject's right eye. The conditioning interval was 400 milliseconds and the conditioned stimulus remained at constant intensity throughout this period. At the beginning of each trial the subject was given a 'ready' signal to which he had been instructed to wink his eyes voluntarily. The conditioning stimuli then followed at an interval of a few seconds. The stimuli and responses were recorded photographically with the Dodge pendulum photochronograph.

The order of trials in the conditioning of the eyelid response was similar to that described in the previous report (4). The first five trials were test trials for response to the conditioned stimulus (the light). Reinforced trials were begun with the sixth trial and 50 such joint presentations of both stimuli at the stated interval were given. Included in each group of ten reinforced trials was one test trial for the unconditioned response, *i.e.*, the puff of air was given alone without the preceding light. At the conclusion of the series of 50 reinforced trials a brief extinction period was run in which ten trials of the light alone were given. The interval between successive trials varied around 30 seconds.

The Conditioned Patellar Responses

The procedure used in the conditioning of the patellar reflex was modelled after the technique described by Schlosberg (12) (13) with certain changes suggested by preliminary investigation. The conditioned stimulus was a sound given through the activation of a small buzzer. Mechanical stimulation of the patellar tendon (the unconditioned stimulus) was effected through the use of a movable knee-stall which was fitted over the subject's right knee. A stimulating hammer, magnetically released, fell through an arc of 90 degrees and struck the back of a narrow hardwood bar which was held gently against the subject's patellar tendon. The activation of the bar by the hammer was transmitted directly to the tendon and produced the patellar response. The conditioning interval was 300 milliseconds, the buzzer sounded continuously until the tendon had been struck.

To facilitate the progress of conditioning the subject was required to give a voluntary hand response to the sound of the buzzer. A rubber bulb was placed in his right hand and his instructions were to squeeze the bulb each trial as rapidly as possible when he heard the buzzer. The two stimuli, the patellar reaction, and the voluntary hand response were all recorded photographically with the photo-chronograph. The patellar responses were transmitted into the recording system through a lever device which was activated by the thickening of the quadriceps muscle of the stimulated leg.

The order of trials resembled that employed in the conditioning of the eyelid response. The first five trials were test trials for the conditioned response, *i.e.*, the buzzer was sounded without reinforcement. The reinforced series was then begun and continued through 100 trials in groups of ten. In each of these groups were included one test trial for the unconditioned response and one test trial for the conditioned response. At the conclusion of the reinforced series ten unreinforced trials were given to produce extinction of the conditioned response. The interval between successive trials varied around 30 seconds.

It will be noted that the two procedures were in many respects very similar. The instructions to the subjects, the order of stimuli, and the physical surroundings of the experimental situations were essentially alike. It was thought advisable to equalize these factors as far as possible so as to minimize the importance of whatever influence they might have had on the conditioning scores which were obtained.

The Subjects

The subjects of the experiment were 49 college students, all men, most of them sophomores. No selection was made except on the basis of sex. The naivete of the subjects regarding the concept of conditioning was in most cases complete. None of them expressed any insight into the object of the study and no enlightenment was offered until the experiment had been concluded. Each subject served three hours on consecutive days, the first session being devoted to eyelid conditioning and the second and third to the conditioning of the patellar response.

Results

The responses given by the subjects in the two conditioning situations fall into two categories: first, the reflex responses to the unconditioned stimuli which denote reflex sensitivity, and second, the conditioned responses to the conditioned stimuli which denote ease of conditioning. In the following section is presented a detailed consideration of these responses, the scores by which they are measured, their reliabilities, their variations between different individuals, and their interrelationships.

Scores; Reliabilities

1. *Reflex Sensitivity.*—Conditioning is ordinarily based on some response which may be regularly evoked by a specific type of stimulation; usually this response is of reflex nature. In this experiment two such underlying reflexes were present: the eyelid reflex to air-puff, and the patellar reflex to tendon stimulation. In addition to these there was present in most subjects a third reflexive response, the eyelid reflex to light. These responses appeared in two types of trials, those in which the stimulus in question was presented alone (test trials), and those in which it was presented along with a second stimulus (joint trials). As described in the Procedure, the test trials were in all cases (except those involving the reflex to light) interspersed at set intervals in the conditioning series of joint (reinforced) trials. The test trials for the reflex to light were given before the conditioning series was begun.

a. Scores denoting reflex sensitivity.—The relative sensitivity of these reflexes was measured in each case in terms of amplitude. This score was obtained by totalling the ampli-

tudes in millimeters of all the responses given and dividing this sum by the total number of stimulations.

b. Reliability of the scores of reflex sensitivity.—To obtain reliability coefficients for the scores of reflex sensitivity a segment versus segment division was used in which a combination of the responses given during the first quarter and the last quarter of the trials was opposed to the responses given during the middle 50 per cent of the trials. Table 1 presents

TABLE 1

RELIABILITIES OF THE SCORES OF REFLEX SENSITIVITY (SEGMENT VERSUS SEGMENT) (Joint trials)

	Amplitude		
	N	*r*	P.E.
Eyelid reflex to light	49	.95	.01
Eyelid reflex to puff	49	.92	.02
Knee-jerk to tap	49	.97	.01

the reliabilities [1] of the joint trial scores of the three reflexes. It may be seen that the coefficients are high in each case.[2]

The test trial scores of the reflexes were in all cases based on too few trials to allow a split-half correlation but an indication of their reliabilities may be obtained from their correlations with the corresponding joint trial scores. These coefficients, as shown in Table 2, range from $r = .86$ to $r = .82$.

TABLE 2

THE RELATIONS OF TEST TRIAL REFLEX RESPONSES TO JOINT TRIAL REFLEX RESPONSES

	Amplitude		
	N	*r*	P.E.
Eyelid reflex to light	49	.82	.03
Eyelid reflex to puff	49	.85	.03
Knee-jerk to tap	49	.86	.03

[1] None of the split half reliabilities reported in these tables has been stepped up by the Brown-Spearman prophecy formula.

[2] Several of the correlations reported in the subsequent tables are based on skewed distributions. It should be mentioned that none of these coefficients was markedly altered by the exclusion of the extreme arrays.

2. *Ease of Conditioning.*—The presence of conditioning is usually evidenced by the appearance of a new response to a previously inadequate stimulus. It has been shown by a number of experimenters that the ease with which such modifications may be effected varies greatly from one individual to another. These individual distinctions may be variously expressed.

a. Scores denoting ease of conditioning.—As described in a previous report (2) ease of conditioning may be expressed in at least four ways. The traditional method is the *criterion* score. Related to this is *frequency*. Accurate recording devices have made possible the measurement of *amplitude* and *latency*.

In both experimental procedures followed in this study the anticipatory responses given during the course of the training period were measured and they serve as the principal means of identifying ease of conditioning. The extinction series of test trials following each of the training periods gave a further measure of conditioning. In the case of the knee-jerk supplementary evidence was obtained from the interspersed test trials previously described. Frequency, amplitude, and latency scores were obtained for both the test trial and the joint trial responses in both conditioning situations. Criterion scores were not computed since it is impossible to obtain a reliability coefficient for this type of score and because it has been shown (2) that criterion and frequency are to a large degree equivalent measures.[3]

b. Reliability of the conditioning scores.—In Table 3 are given the reliabilities of the three conditioning scores as determined from the anticipatory (joint trial) responses. The same segment versus segment division of data described above was used. Frequency and amplitude are in both cases more reliable than latency. The coefficients for the eyelid responses are very similar to those previously reported (2).

The range of frequency of the test trial responses as measured during extinction was in all cases too limited to

[3] In those cases where no conditioned responses were present zero scores were given for frequency and amplitude. However, no scores was available for latency in such instances.

TABLE 3
RELIABILITIES OF THE SCORES OF EASE OF CONDITIONING
(SEGMENT VERSUS SEGMENT)
(Anticipatory conditioned responses)

	Eyelid			Knee-jerk		
	N	*r*	P.E.	*N*	*r*	P.E.
Frequency	49	.86	.03	49	.80	.03
Amplitude	49	.91	.02	49	.88	.02
Latency	48[3]	.74	.04	37	.67	.06

permit the segment versus segment analysis. Accordingly the reliabilities of the scores obtained on these trials were approximated by correlating the test trial scores with the corresponding scores of the anticipatory (joint trial) responses. It is clear from the coefficients presented in Table 4

TABLE 4
THE INTERRELATIONS OF ANT ICIPATORYAND EXTINCTION CONDITIONED RESPONSES

	Eyelid			Knee-jerk		
	N	*r*	P.E.	*N*	*r*	P.E.
Frequency	49	.66	.05	49	.60	.06
Amplitude	49	.62	.06	49	.74	.04
Latency	46	.23	.10	28	.43	.10

that anticipatory conditioned responses and extinction conditioned responses are to some degree measures of the same thing. All of the coefficients are positive and only one is not significant.

The correlations given in Table 5 point out the relation-

TABLE 5
THE RELATIONS OF TEST TRIAL CONDITIONED RESPONSES TO EXTINCTION AND ANTICIPATORY RESPONSES (PATELLAR RESPONSES ONLY)

		Anticipatory			Extinction		
		N	*r*	P.E.	*N*	*r*	P.E.
Test Trial	Frequency	49	.71	.05	49	.76	.04
	Amplitude	49	.86	.03	49	.74	.04
	Latency	34	.43	.09	28	.56	.09

ships existing between the interspersed test trial responses obtained during the patellar conditioning and the anticipatory responses so obtained. These coefficients are essentially comparable to those obtained between the anticipatory and extinction patellar responses. They further emphasize the similarity of the anticipatory and test trial methods of measuring the presence of conditioning.

The size of the reliability coefficients presented in these tables shows clearly that the conditioned eyelid and patellar responses are subject to reliable measurement. The three conditioning scores are apparently not of equal consistency, frequency being the most reliable and latency the least.

d. Interrelations of the scores denoting ease of conditioning. —Table 6 presents the relations of the three conditioning

TABLE 6

INTERRELATIONS OF THE SCORES OF EASE OF CONDITIONING (ANTICIPATORY RESPONSES)

	Frequency			Amplitude		
	N	*r*	P.E.	*N*	*r*	P.E.
Eyelid						
Amplitude	49	.26	.09			
Latency	48	−.44	.08	48	−.22	.09
Knee-jerk						
Amplitude	49	.63	.06			
Latency	37	−.27	.10	37	−.27	.10

scores (frequency, amplitude, and latency) to each other. Considering only the anticipatory responses the relationships are consistent for both reflexes studied. Frequency and amplitude may be seen to be positively related in each case. For the eyelid responses the coefficient is surprisingly low in view of the correlation of these variables ($r = .56$) obtained by Campbell and Hilgard (**2**). Latency is negatively related to both frequency and amplitude although the coefficient is significant only for the correlation between the frequency and latency of the eyelid responses.

Individual Differences

As is usually the case in conditioning experiments, the subjects varied greatly in their reactions to the experimental

procedures. The individual differences were pronounced, both in reflex sensitivity and in ease of conditioning.

1. *Differences in Reflex Sensitivity.*—Figure 1 shows the differences between subjects in their responses to the three

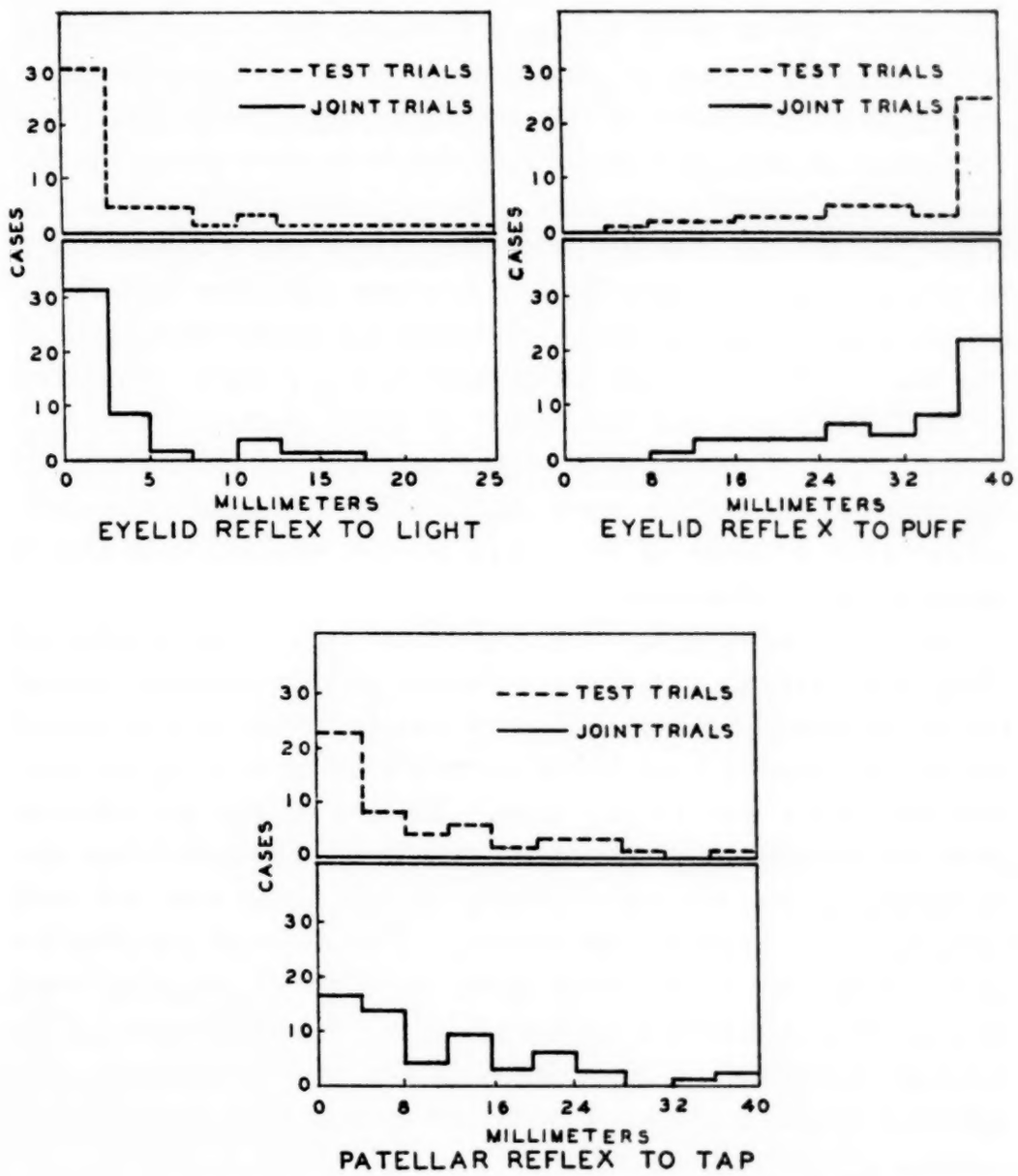

FIG. 1. Individual differences in reflex sensitivity ($N = 49$ in each graph).

reflex-provoking stimuli. The curves showing the average amplitudes of the eyelid responses to the light (joint trials and test trials) are positively skewed, indicating that for most of the subjects this stimulus was not very efficacious. The curves showing the reflex responses to the air-puff indicate

that in most cases the puff was an effective stimulus. The amplitudes of the reflex responses to the patellar stimulations were in most cases small although several of the subjects reacted quite violently.

2. *Differences in Ease of Conditioning.*—In Figure 2 are presented curves showing the differences between individual subjects in their ease of conditioning as herein determined.

At the conclusion of 50 training (reinforced) trials the frequency of the anticipatory eyelid responses given by the 49 subjects varied from zero to 92 per cent and the mean of these frequencies was 46 per cent. Only one subject failed to give at least one anticipatory response and over half of the subjects gave anticipatory responses on more than half of the trials. The average amplitude scores ranged from zero to 40 millimeters and the mean of these averages was 11.5 millimeters. The averages of the latencies of each subject's anticipatory responses were distributed approximately normally with a range of from 149 to 372 milliseconds and a mean of 246 milliseconds.

In the conditioning of the patellar reflex 100 reinforced trials were given. At the conclusion of this training period the frequencies of the anticipatory patellar responses obtained during this session were found to vary from zero to 54 per cent and the mean was 11 per cent. Twelve of the 49 subjects gave no anticipatory responses and it is apparent from the distribution that the conditioning of this reflex was not well established in most of the others. The average amplitudes of the responses which were given were small, varying from zero to 16.5 millimeters with a mean of 2.6 millimeters. The average latencies of each individual's responses were distributed within a range of from 180 to 290 milliseconds with a mean of 238 milliseconds.

The distributions shown in Figure 2 not only demonstrate the differences which exist between individuals in the ease with which they form conditioned responses but they also permit a comparison of the relative ease with which these two reflexes yield to conditioned modification. When measured by the frequency of the anticipatory responses the patellar

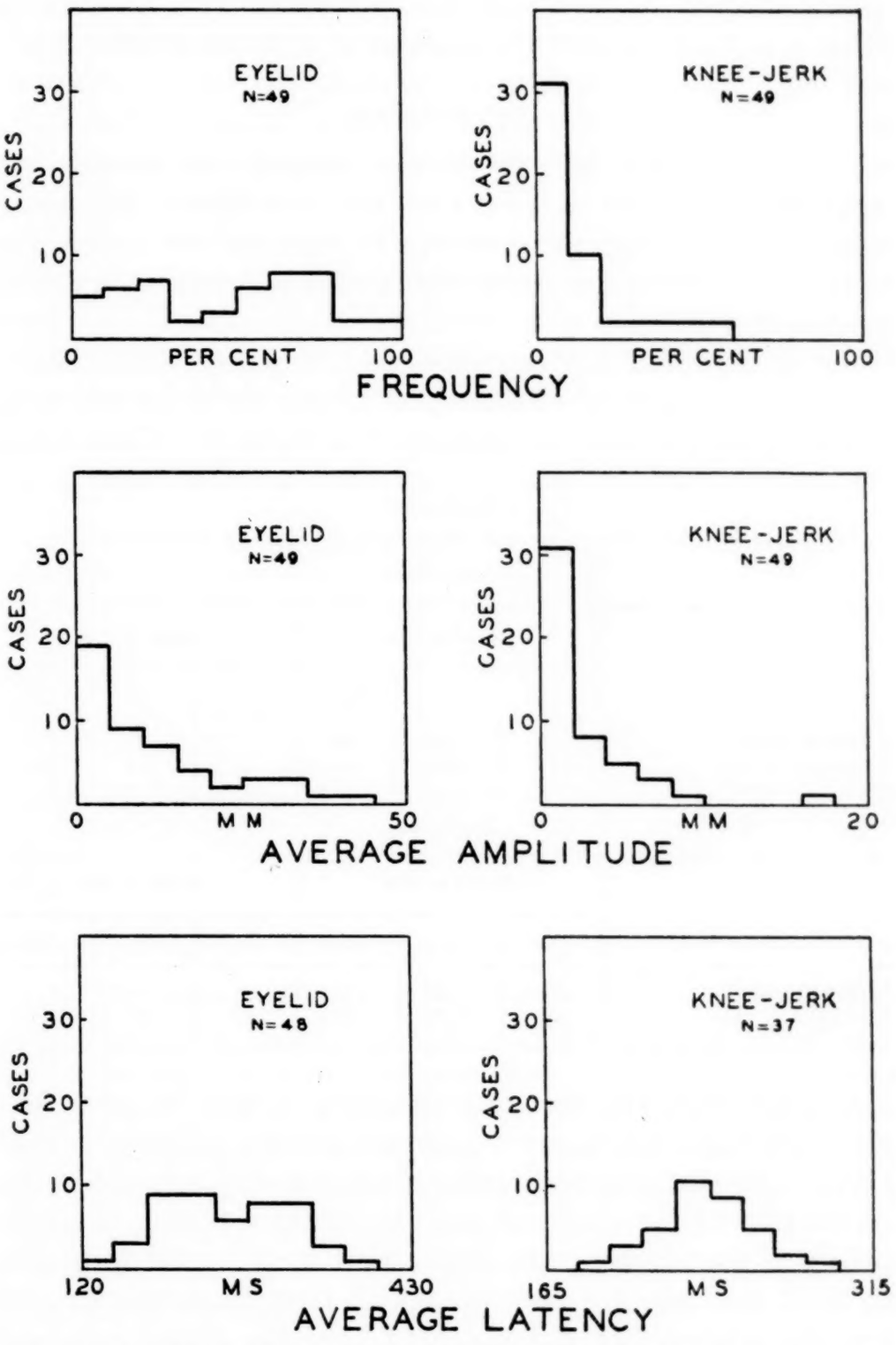

FIG. 2. Individual differences in ease of conditioning (anticipatory responses).

reflex is seen to be much less amenable to conditioning. This is in keeping with the findings of previous studies.

Interrelations

The foregoing analysis of the methods of scoring, the reliabilities of the scores, and the individual differences among the subjects provides the background for a consideration of the intercorrelations which exist between the different responses.

1. *Correlations between Measures of Reflex Sensitivity.*— The intercorrelations of the scores of sensitivity to the three reflex-eliciting stimuli are presented in Table 7. Considering

TABLE 7

THE INTERRELATIONS OF THE MEASURES OF REFLEX SENSITIVITY

Joint Trials

	Eyelid to light			Eyelid to puff		
	N	*r*	P.E.	*N*	*r*	P.E.
Eyelid to puff	49	.36	.08			
Knee-jerk to tap	49	.18	.09	49	.18	.09

Test Trials

	Eyelid to light			Eyelid to puff		
	N	*r*	P.E.	*N*	*r*	P.E.
Eyelid to puff	49	.26	.09			
Knee-jerk to tap	49	−.03	.10	49	.36	.08

both joint trial and test trial averages it may be seen that the coefficients are in every case too low for statistical reliability. The greatest indication of relationship is found in the correlation of the scores of the two eyelid reflexes. Investigation of the scatter-plots shows that large eyelid responses to light were usually associated with large responses to puff but the relationship did not hold over the entire range of scores. These correlations lead to the conclusion that reflex sensitivity, as measured in this experiment, is almost completely specific to each individual reflex.

2. *Correlations between Measures of Ease of Conditioning.*—Table 8 presents the correlations between the conditioning scores for both joint trials and test trials obtained from the two conditioning situations. As may be seen, with the 49 subjects serving in this experiment ease of conditioning was completely specific to each situation. No evidence of any generality in this trait is shown. All of the coefficients in Table 8 range around zero and there is no consistency in their sign. It is clear that with these data it is impossible to predict any subject's reaction to one of the conditioning procedures from a knowledge of his response to the other.

TABLE 8

THE INTERRELATIONS OF THE MEASURES OF EASE OF CONDITIONING (EYELID CONDITIONING *vs.* PATELLAR CONDITIONING)

Anticipatory Conditioned Responses

	N	*r*	P.E.
Frequency	49	−.14	.09
Amplitude	49	.02	.10
Latency	37	−.32	.10

Extinction Conditioned Responses

	N	*r*	P.E.
Frequency	49	.03	.10
Amplitude	49	−.13	.10
Latency	27	−.04	.13

3. *Correlation between Reflex Sensitivity and Ease of Conditioning.*—The data reviewed in the preceding paragraphs fail to reveal any significant tendency toward intercorrelation either among the measures of reflex sensitivity or among the measures of ease of conditioning. However, when the scores of these two variables are correlated with each other certain consistent relationships are brought out.

It has been known since Pavlov's original studies that the sensitivity of a reflex and the ease with which a conditioned response can be developed from it are related factors. The presence of this relationship is clearly evidenced in Table 9. The frequency and amplitude scores of the conditioning measures are in each case positively related to the corre-

sponding measures of reflex sensitivity. The latency scores of conditioning are negatively correlated with the reflex measures. These relationships conform to Pavlov's observation that the more responsive an unconditioned reflex is, the more readily a conditioned response based upon it may be developed.

The correlations between the scores of eyelid conditioning and the amplitude score of the reflex to light give some indication that eyelid conditioning was more firmly established in those subjects who were most sensitive to the conditioned stimulus.

TABLE 9

THE INTERRELATIONS OF THE MEASURES OF EASE OF CONDITIONING AND REFLEX SENSITIVITY

(*Joint Trials*)

	Eyelid to Light Amplitude			Eyelid to Puff Amplitude				Knee-jerk to Tap Amplitude		
	N	*r*	P.E.	*N*	*r*	P.E.		*N*	*r*	P.E.
Eyelid CR'S							Patellar CR's			
Frequency....	49	.46	.08	49	.47	.08	Frequency.....	49	.29	.09
Amplitude....	49	.20	.09	49	.41	.08	Amplitude.....	49	.26	.09
Latency.....	48	−.10	.10	48	−.17	.09	Latency.....	37	−.03	.11

DISCUSSION

Individual Differences in Ease of Conditioning.—The distributions presented in Fig. 2, showing the differences in the relative ease with which the subjects established the two conditioned responses, give no evidence of the presence of conditioning types. There is a slight bi-modality in the curve of frequency scores for the conditioning of the eyelid reflex but it cannot be considered significant. None of the other distributions shows this division.

The curves showing the differences between the subjects in their frequency and amplitude scores in the conditioning of the patellar reflex are both distinctly J-shaped. As anticipated this reflex yielded slowly to conditioned modification. Razran (**10**) has suggested that if patellar conditioning of this type were carried beyond "its initial stage, the

curve (of individual differences) would become fully U-shaped." There are no data in support of this postulate and there appears to be little reason to expect such a change in the distribution to take place. It has been demonstrated by Campbell and Hilgard (**2**) that in the conditioning of the eyelid reflex extension of the training series progressively transforms the original J-shaped distribution curve of frequency scores into a negatively skewed curve with the mode gradually approaching the upper limit. It seems probable that this would also be the case in patellar conditioning.[4] In any event it is clear that distributions of individual differences based on frequency or amplitude scores will change as conditioning progresses and no stage of this development can be taken as a general representation of any particular type of conditioning.

Attitude as a Determiner of Conditioning Scores.—Razran (**10**) (**11**) has recently proposed a 'tri-attitudinal bi-factoral reservoir theory' of human conditioning. This theory contends that "after a few combined presentations of the conditioned and conditioning stimuli, the subjects assume certain attitudes—positive, negative, and indifferent—toward the conditioning situations; these attitudes . . . control the incidence of the CR's, the magnitudes of which are determined by physico-physiological factors." While the theory was propounded from a study of conditioned salivation Razran feels it may be applied to the conditioning of 'any consciously reportable and consciously controllable response.' Consideration of the data of the present study and others suggests that Razran has applied his hypothesis too broadly.

The most obvious objection arises from the fact that distributions of frequency scores are not commonly U-shaped as the theory demands and as pointed out above there is evidence indicating that these curves do not become U-shaped when the training series is extended. From consideration of

[4] It is obvious that the curve must perforce become U-shaped if the distribution contains subjects who have no unconditioned response to patellar stimulation since no number of reinforced trials will produce a conditioned response in an unresponsive subject. This bi-modality could scarcely be attributed to the influence of divergent attitudes however.

the numerous distribution curves now in the literature it should be apparent that no typical distribution of conditioning scores can be assumed. Such distributions vary greatly with differences in any one of several factors in the experimental situations. The most consistent characteristic of curves obtained under these diverse experimental conditions is the absence of conditioning types. Distributions showing distinct bi-modality or multi-modality are exceptional and Razran's identification of six separate types from a study of 37 subjects is extraordinary.

The theory seems likewise misapplied in the case of the numerous studies (including the present one) in which the conditioning is not 'sporadic and inconstant' but predictably stable. The instability observed by Razran in his study of conditioned salivation has also been reported by Marquis and Porter (**5**) from their study of eyelid conditioning based on voluntary eyelid closure. Under these experimental circumstances the "curves of acquisition and extinction did not show the gradual and progressive changes characteristic of conditioned involuntary responses. These results indicate that conditioned voluntary responses are descriptively and functionally different from comparable conditioned involuntary responses." While it is probable that the two kinds of conditioning studied by these authors do not constitute a strict dichotomy from the point of voluntary or reflex basis, it is clear that the conditioning of 'involuntary responses' does not conform to Razran's description.

Finally, in considering the importance of attitude, it should not be overlooked that incidence of conditioning has been shown to be significantly related to at least two other factors, namely the sensitivity of the unconditioned reflex and the intensity of the conditioned stimulus. Pavlov himself first noted the relationship between ease of conditioning and reflex sensitivity and his observation has been corroborated several times by subsequent experimenters. Razran's negative findings are distinctly atypical. The relationship between the strength of the conditioned stimulus and speed of conditioning was also observed by Pavlov and is clearly

demonstrated in the findings of the present study. Correlations of the same order were obtained in a previous analysis of eyelid conditioning by Campbell and Hilgard (**2**).

According to Razran's bi-factoral concept, incidence of conditioning is determined by a psychological factor ('a direct function of past associations, of verbal-conscious integrations') and does not result from 'differences in physiological reactions.' It is evident from the correlations just cited that incidence of conditioning as measured in this experiment was to a significant degree a function of physiological factors. Razran states further that frequency and amplitude scores of conditioning result from the operation of two distinct factors and are unrelated. In this connection it should be noted that both in this study and in previous research (**2**) these two scores have been found to be significantly correlated.

There can be no doubt that the subject's attitude is an important consideration in conditioning experiments. It is apparent, however, that in procedures such as those used in the present study there are also other factors operating, the significance of which cannot be summarily dismissed.

The Specificity of Ease of Conditioning.—It can hardly be said from the results of this study that ease of conditioning is completely specific. Further experimentation may bring out clusters of responses possessing common conditioning characteristics. The present findings are sufficient to show, however, that ease of conditioning is not general for all human responses. No generalities regarding an individual's relative susceptibility to conditioning influences can be drawn from the investigation of a single response. Such statements as Razran's that 'hundreds of human subjects' cannot be conditioned at all are obviously without justification. This would imply that each of these individuals had been subjected to all the conditioning procedures known to psychology and had proved negative to all of them.

So far as the writer is aware, there has been no attempt other than the present one to correlate conditioning scores obtained from the conditioning of different reflexes. There

have been, however, several attempts to correlate ease of conditioning (as determined from one conditioning procedure) with such other measures as reaction time, suggestibility, and intelligence test score (**2**). As would be expected from the present findings nearly all of the correlations obtained in these studies have been insignificant: a notable exception is the significantly positive relationship ($r = .59$) found by Mateer (**6**) between speed of conditioning and mental age. It is probable however that this correlation resulted not from an actual relationship between the two variables measured but from the influence of chronological age which was uncontrolled. Mateer found chronological age to be related to speed of conditioning ($r = .57$) and there would appear to be little question that the factor of maturation determined the other coefficients which she obtained.

Summary and Conclusions

In order to investigate the degree of generality present in the ease of conditioning of different human reflexes, 49 college students were subjected to experimental procedures designed to condition the eye-lid reflex to air-puff and the patellar reflex to tendon stimulation. Scores of both ease of conditioning and reflex sensitivity were photographically obtained from each subject for each of the two reflexes. Ease of conditioning was expressed in terms of frequency, amplitude, and latency. Reflex sensitivity was expressed in terms of amplitude. The experimental findings justify the following conclusions:

1. Conditioned eyelid and patellar responses have been found to be subject to reliable measurement. Frequency is a more consistently reliable score than either amplitude or latency.

2. Individual differences are wide in the ease with which these two conditioned responses are formed. In most subjects conditioned eyelid responses are more readily established than conditioned patellar responses.

3. Within the limits of this study conditioning scores obtained from one experimental situation cannot serve as

the basis of prediction of conditioned behavior in a second situation in which a different reflex is measured.

4. The eyelid reflex to light, the eyelid reflex to air-puff, and the patellar reflex to tendon stimulation are characterized by unusually high consistency.

5. Individual differences in the sensitivity of these three reflexes are marked. These three measures of reflex sensitivity are not significantly related to each other.

6. Reflex sensitivity correlates consistently with the ease with which the reflex may be conditioned. Generally speaking, the greater the reflex response to the unconditioned stimulus, the more readily conditioning may be established. Ease of eyelid conditioning is also positively correlated with reflex sensitivity to the conditioned stimulus.

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ADAPTATION OF THE GALVANIC RESPONSE TO AUDITORY STIMULI

BY CLYDE H. COOMBS * †

I. Introduction

A successive decrease in the magnitude of the changes in electrical resistance of the skin in response to repeated stimulation is one of the most characteristic phenomena of the galvanic skin reflex. Though a number of publications on the galvanic reflex have made reference to this phenomenon (**8**) (**9**) (**18**) (**19**) and others are studies of its relation to character (**1**), personality (**6**) and mental abnormality (**13**) (**17**), there has been but little study of galvanic response decrement itself.

A recent publication of R. C. Davis (**7**) casts some light on the factors involved in adaptation. He concludes, in part, that "stimuli composed of a greater number of elements produce constant or increasing reactions." With very complex stimuli galvanic adaptation may be in the reverse direction, the galvanic responses getting greater with repetition. He suggests this as an hypothesis, as his data are not sufficient to warrant a stronger attitude. Also as an hypothesis he suggests that "stimuli which produce a pleasant reaction bring about greater reactions upon repetition; those which produce an unpleasant reaction, cause decreased responses upon repetition, and indifferent stimuli continue to have about the same reaction."

However, there are many aspects to the problem of galvanic adaptation about which nothing is known. A brief survey will be made here which is not intended to exhaust the problem but merely to indicate some of the minor points which upon investigation would yield a clearer insight into the nature of the phenomenon.

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† I wish to express my gratitude for the aid and criticism of Professor Warner Brown in the conduct of the experiment and the preparation of the manuscript.

A. Adaptation versus Fatigue

It is the opinion of the author that galvanic responses are mediated by psychological processes aroused by stimulation and that continuous trends in galvanic response, decrement or increment, are due to the adjustment of these psychological processes in the course of repeated stimulation.

When galvanic responses have successive decrements, it may appear to be due, at first glance, to a fatigue process. Let us consider whether there can be a fatigue process in the galvanic response mechanism. The mechanism underlying the galvanic response in the region to which the electrodes are attached is a temporary change in the permeability of the sweat glands. This increase in the permeability of cutaneous tissue may be brought about by a chemical mediator of excitation between autonomic nerve endings and the glandular tissue.

Experimental support for such an hypothesis may be found in the work of O'Leary (**14**) and Richter (**15**) who have shown the changes in skin resistance to be mediated by the autonomic nervous system, and more direct evidence in a recent report by Dale (**3**) in which he states that the sympathetic nerve supply to the sweat glands of the cat transmits its excitation by liberating acetylcholine. The hypothesis is further supported by the work of Hoagland (**10**) (**11**) and Rubin and Hoagland (**16**) on a humoral mechanism for peripheral sensory inhibition (adaptation), by the work of Darrow (**4**) in showing the relation between sweat secretion (which is probably accompanied by changes in the permeability of the sweat glands) and psychological and galvanic activity, and also by the work of Cannon and Cattell (**2**) in showing that the secretory process of the salivary gland is always accompanied by an electrical change. Fatigue in such a mechanism would probably consist of exhaustion of the supply of the chemical mediator of excitation or the accumulation of waste products inhibiting the activity of the mechanism. That this occurs is rendered improbable by the results of Davis, already quoted, in which he finds that complex stimuli bring about *greater* reactions upon repetition.

Furthermore, if it can be shown that galvanic response decrement is paralleled by changes in the psychological processes aroused by stimulation, then adaptation of the galvanic response may be held to be a centrally located function.

B. Generality versus Specificity (Transfer)

This aspect of adaptation presents two different problems:

1. Is there transfer of adaptation from one sense modality to another or is the adaptation specific to or confined within a single modality?

2. Is there transfer of the adaptation to one stimulus in a given sense modality to another stimulus in the same sense modality, and, if so, to what psychological attribute or physical characteristic of the stimulus is this generality referable?

There is also another kind of adaptation which is met in studies of the galvanic skin reflex and which may not be attributed to a characteristic of the stimuli. Naïve subjects coming into an experimental room containing the apparatus required by such experiments are apt to feel somewhat uneasy. As the experiment progresses and its mild nature is apparent the subject loses his uneasiness and there results a general adjustment to the situation. The early uneasiness of the subject is probably one which would heighten his reactivity regardless of the modality or specific nature of the stimulus. In other words, there is probably complete transfer of this kind of adaptation, except in so far as a change in the nature of the stimuli presented may give rise to further uneasiness.

C. Factors Affecting Adaptation

There are many conditions which interact in the course of adaptation each of which must be investigated independently.

These conditions include the following: (1) The effect of the duration of the stimulus. For example, what is the course of adaptation to a momentary stimulus as compared with one of several seconds duration? (2) The effect of time interval between stimuli. It is perhaps to be expected that shorter intervals between stimuli will result in quicker adaptation.

Investigation of galvanic adaptation should also be made with respect to the physical nature of the stimulus and also with respect to the psychological processes it tends to arouse. Thus it may be that such physical characteristics of stimuli as pitch, intensity, etc., or such psychological processes as affectivity and startle bear a relation to galvanic adaptation which if revealed would lead to a clearer understanding of the nature of the galvanic reflex as well as galvanic adaptation.

The purpose of the present experiment was to investigate the relation of startle, affectivity, and the time interval between stimuli to galvanic adaptation.

II. The Experiment

A. Subjects

The subjects were 187 women students and adults, attending courses in psychology at the University of California during the Intersession, Summer Session, and the Fall semester of 1935.

B. Stimuli

1. *Phone.*—This was the tone of a tuning fork (1000 dv.) amplified by means of a General Radio audio oscillator. The sound was produced about two feet directly above the subject's head. All other stimuli came from behind the subject.

2. *Horn.*—A typical automobile klaxon.

3. *Clapper.*—A strip of resilient steel, ten inches long and one half inch wide. A screen about six feet square and made of wallboard was behind the subject's chair and one end of the strip of steel was attached to the back side of the screen about on a level with the subject's shoulders. The other end was drawn back two inches and caught behind a trigger. The trigger was released by pulling a string and the steel strip snapped sharply against the back of the screen.

4. *Knocker.*—This was a small electric soundhammer listed in E. Zimmerman's catalogue 50 as No. 1426 (Kleiner Schallhammer). The hammer is caused to knock against a resonating box by an electro-magnet, producing a sharp clicking sound of short duration.

5. *Buzzer.*

6. *Gong.*—The gong was a cylinder of seven-thirty-seconds inch brass, twelve inches high, three and one half inches in diameter, and closed at the base. A three-inch bolt was in a spring arrangement in such a manner that it could be pulled back and let snap against the brass cylinder. The sound was bell-like and resonated for about three seconds.

C. Galvonometer Apparatus

1. The electrodes were made of silver foil, one inch square. These had a three inch by one-quarter inch extension to the end of which was attached a tin strip. To the latter were attached the wires leading to the bridge. All these connections were soldered and shellacked to make them water-proof, and then taped.

2. The electrolyte was made of kaolin paste mixed with nine-tenths per cent salt solution. One electrode was placed on the palm of the left hand, the other electrode

was placed on the inside of the left forearm, midway between elbow and wrist. A piece of rubber dam, five inches square, was laid over the electrode after the latter had been placed in position. A ball of cheese cloth was laid on this and the hand or arm wrapped in a strip of rubber dam, three inches wide and twenty-four inches long, as tightly as possible without impeding the circulation.

3. The galvonometer set-up was a copy of the Behavior Research Resistance Box used by C. W. Darrow (5).

The high resistances employed in this circuit necessitated the use of a relatively high external potential. Three dry cells (4.5 v.) were found to give a sufficiently high potential.

4. The galvanometer used was a Leeds and Northrup portable D'Arsonval (galvanometer system 2428c) with a three and one half second period, a critical damping resistance of 15,000 ohms, and with a 1000-ohm coil. The distance from the galvanometer to the recording paper was about eight inches giving a sensitivity of 3100 ohms/inch with this particular bridge and shunt, and with four and one half volts applied to the bridge. The shunt together with the bridge resistances was experimentally chosen to critically damp the galvanometer.

5. A beam of light was reflected by the galvanometer mirror through a slit on a roll of adding machine paper, two and one half inches wide, which was drawn past the slit at a constant rate by a motor. The light was followed manually with a pencil. This method does not permit an accurate determination of latent time but does permit, with sufficient accuracy, the determination of the absolute magnitude of the deflection.

D. Procedure

The experiment was carried out in a soundproof room, with the subject seated in a comfortable armchair. The subject was unable to see the apparatus due to a screen made of wall board immediately behind the chair.

Upon the wall in front of the subject were hung two cards. One was an affectivity rating scale with gradations from one to seven; the other card was a startle rating scale with gradations from one to five.

Affectivity Rating Scale

1. Very pleasant
2. Pleasant
3. Neither pleasant nor unpleasant
4. Slightly unpleasant
5. Definitely unpleasant
5. Very unpleasant
7. Extremely unpleasant

Startle Rating Scale

1. No startle at all.
2. Only slightly startled
3. Moderately startled
4. Very startled
5. Extremely startled

The subject was instructed to choose a number from each scale fitting to the stimulus presented and to repeat the numbers aloud when asked for rating by the experimenter. This verbal response of the subject was delayed until the galvanic response to the auditory stimulus had been completed, usually a matter of ten to fifteen seconds.

The horn, knocker, phone, and buzzer were sounded by pressing a telegraph key, the gong by pulling back and releasing a plunger, the clapper by pulling a string. The noises were presented by an assistant every thirty seconds, with certain exceptions noted below. The assistant timed the intervals between stimuli by means of an electrical clock with a second hand on the face of the dial.

After the subject was seated and the electrodes were in place, the current was turned on. A period of three to four minutes was usually required for the subject's resistance to reach a relatively stable level. The motor for turning the recording paper was started and the subject received the final instructions.

Instructions

"Will you please sit quietly and avoid movement particularly of your left arm. You will hear a series of noises about every thirty seconds. Will you please look at the left rating card and give a number to the noise according to how it affects you. Then look at the rating card on the right and give a number according to how much the sound startled you. Do not give the numbers when you hear the noise, but wait until I ask for them. Is that understood?"

The subjects were given thirty-three stimuli divided into two parts. Part I comprised fifteen stimuli which were all repetitions of the phone. About half the subjects received these fifteen stimuli, as well as all the other stimuli, at thirty second intervals (these will be referred to as the thirty-second subjects). The remaining half of the subjects received the first five phone stimuli at fifteen second intervals, but all remaining stimuli at thirty second intervals (these will be referred to as the fifteen-second subjects). Part II began with the sixteenth stimulus, following the fifteenth stimulus after thirty seconds. Part II comprised a group of six different stimuli repeated twice. These six stimuli were presented in six different orders obtained by simply rotating the original order. Each of the orders is referred to as a series. The order of the stimuli in the six series and position in which each stimulus occurs is presented in the following table.

PART II

THE ORDER AND POSITIONS OF THE STIMULI COMPRISING A SERIES

Position	Series I	Series II	Series III	Series IV	Series V	Series VI
16.	*Horn*	Clapper	Phone	Knocker	Buzzer	Gong
17.	Clapper	Phone	Knocker	Buzzer	Gong	*Horn*
18.	Phone	Knocker	Buzzer	Gong	*Horn*	Clapper
19.	Knocker	Buzzer	Gong	*Horn*	Clapper	Phone
20.	Buzzer	Gong	*Horn*	Clapper	Phone	Knocker
21.	Gong	*Horn*	Clapper	Phone	Knocker	Buzzer
22.	*Horn*	Clapper	Phone	Knocker	Buzzer	Gong
23.	Clapper	Phone	Knocker	Buzzer	Gong	*Horn*
24.	Phone	Knocker	Buzzer	Gong	*Horn*	Clapper
25.	Knocker	Buzzer	Gong	*Horn*	Clapper	Phone
26.	Buzzer	Gong	*Horn*	Clapper	Phone	Knocker
27.	Gong	*Horn*	Clapper	Phone	Knocker	Buzzer
28.	*Horn*	Clapper	Phone	Knocker	Buzzer	Gong
29.	Clapper	Phone	Knocker	Buzzer	Gong	*Horn*
30.	Phone	Knocker	Buzzer	Gong	*Horn*	Clapper
31.	Knocker	Buzzer	Gong	*Horn*	Clapper	Phone
32.	Buzzer	Gong	*Horn*	Clapper	Phone	Knocker
33.	Gong	*Horn*	Clapper	Phone	Knocker	Buzzer

The thirty-second subjects were divided into six groups of at least fifteen subjects each. Each group was run on a different one of these series. Similarly, the fifteen-second subjects were divided into six groups of at least fifteen subjects each, and each of these groups was run on a different one of the series. Hence about thirty subjects were run on each series, half of them being thirty-second subjects and half of them being fifteen-second subjects.

Thirty-second and fifteen-second subjects were selected in random order, and for each subject one of the six series of stimuli was chosen at random.

III. Results

A. Reliability

For determination of reliability the first fifteen stimuli, all being the same, were used with the exception of the first one because of its great position effect. The remaining fourteen were divided into an odd-even split-half and the mean absolute deflection for odd and for even stimuli was calculated for each subject. These were correlated, treating fifteen-second subjects and thirty-second subjects separately.

The split-half correlation was also made for these two groups of subjects on the second to seventh stimulus (P_2–P_7) inclusive and again on the eighth to fifteenth (P_8–P_{15}) inclusive. The obtained reliabilities were stepped-up by the Spearman-Brown formula and the results are given in Table I.

TABLE I
Reliability

Stimuli	Split-Half				$\frac{2R}{1+R}$	
	15″		30″		15″	30″
	N	*R*	*N*	*R*	*R′**	*R′**
P_2–P_7	93	.79	88	.74	.88	.85
P_8–P_{15}	90	.77	85	.73	.87	.85
P_2–P_{15}	93	.88	92	.76	.93	.86

* R' is the stepped-up reliability.

The difference in reliability of fifteen-second and thirty-second subjects are not statistically significant.

B. Effect of Position

The thirty-second subjects were given the phone as stimulus fifteen times at thirty second intervals. The mean

deflection of these ninety subjects was calculated at each of the fifteen positions. The mean deflection for each of the positions from sixteen to thirty-three is an average of six groups of subjects each group receiving a different stimulus. The graph showing the mean absolute deflection in each of the thirty-three positions is presented in Figure 1. Figure 1 also contains a graph of the mean startle rating and the mean affectivity rating for each position.

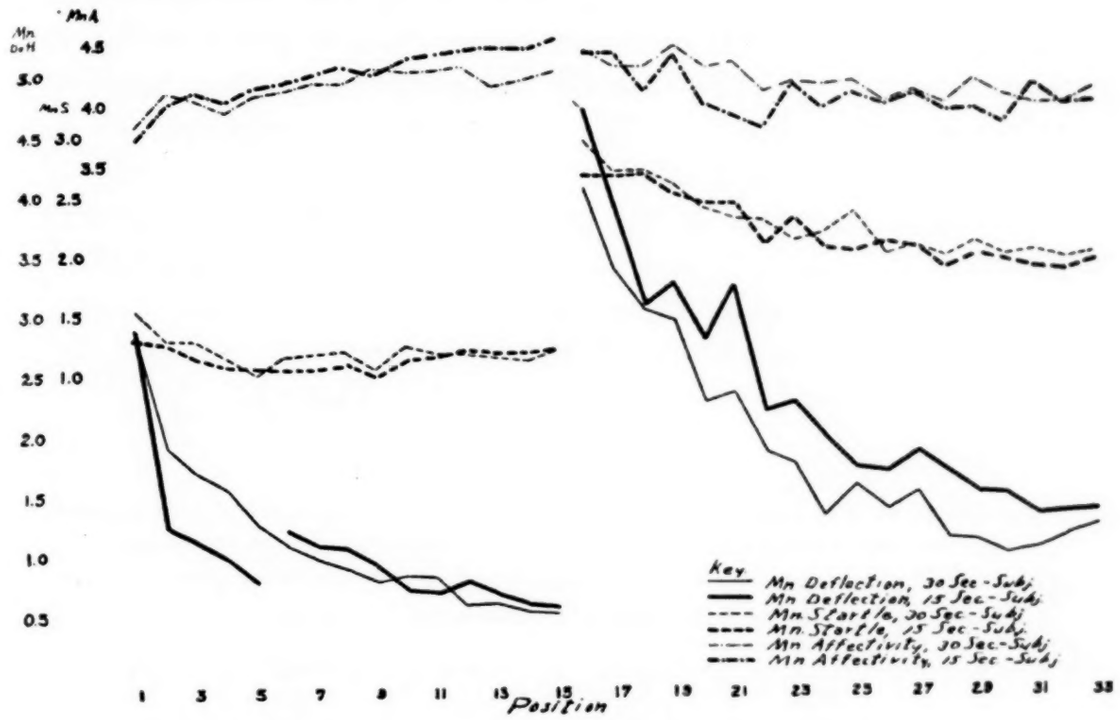

FIG. 1. Mean deflection, mean startle, and mean affectivity for positions 1–33 for both fifteen-second subjects and thirty-second subjects.

For thirty-second subjects the plot of the first fifteen positions against their respective mean absolute deflection indicates that the rate of adaptation is more rapid at first than later. Adaptation does not appear to be complete even by the fifteenth presentation, but the curve is definitely approaching a plateau.

At position sixteen the curve takes a sudden jump upward, due to the different stimuli presented at this point. From position sixteen to thirty-three adaptation again takes place and at what appears to be a rate similar to that for the first fifteen positions.

C. *Effect of Time Interval*

The effect of time interval may be investigated by comparing the mean deflections of thirty-second subjects with the mean deflections of fifteen-second subjects. The fifteen-second subjects were given the same stimuli as the thirty-second subjects and at the same time intervals except that the first four intervals were fifteen seconds long instead of thirty. All the other intervals were thirty seconds.

A graph of the mean deflections of the fifteen-second subjects in each of the thirty-three positions is given in Fig. 1 also, where it may be directly compared with that for the thirty-second subjects. The means were computed in a manner identical with that for the thirty-second subjects.

Certain positions in the graph are of particular interest, positions 2, 3, 4, 5, 6, and 16. The significance of the difference between the mean deflection of the thirty-second subjects and the mean deflection of the fifteen-second subjects for each of these six positions is presented in Table II.

TABLE II

SIGNIFICANCE OF THE DIFFERENCE BETWEEN THE MEAN DEFLECTIONS OF FIFTEEN-SECOND AND THIRTY-SECOND SUBJECTS IN CERTAIN SELECTED POSITIONS

Position	15″ Means	30″ Means*	Difference†	σ diff.	c.r.
2	1.282	1.951	0.669	0.194	3.45
3	1.195	1.754	0.559	0.199	2.81
4	1.05	1.51	0.46	0.183	2.53
5	0.817	1.338	0.52	0.164	3.18
6	1.335	1.179	0.156	0.173	0.9
16	4.71	3.95	0.76	0.557	1.36

* Mean deflections are all expressed in thousands of ohms.

† The sign, or direction, of the difference is of no account in the table.

A comparison of the curve of fifteen-second and thirty-second subjects for mean absolute deflections in the first fifteen positions (Fig. 1) clearly indicates that adaptation takes place more rapidly with a fifteen second interval than with a thirty second interval. The fifteen-second subjects have reached a level of response by the fifth presentation about equal to that of the thirty-second subjects by the tenth presentation. But there is not sufficient evidence to draw

the conclusion that adaptation is twice as rapid with fifteen second intervals as it is with thirty second intervals.

It is noteworthy that the significantly greater adaptation of the fifteen-second subjects by position five does not appear to have any transfer effect to any of the later positions as none of them show a significant difference between the mean deflection for fifteen-second subjects and for thirty-second subjects (*i.e.* position 1). The differences that appear seem to be due to sampling error.

The course of the resistance level over the thirty-three positions was determined for fifteen- and thirty-second sub-

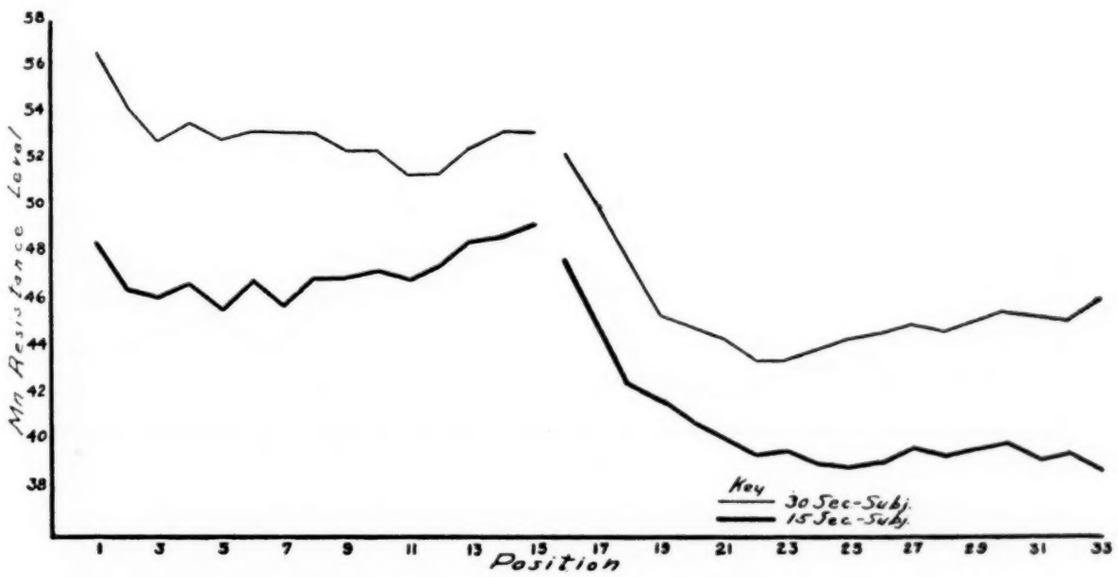

FIG. 2. Mean resistance level.

jects. The mean resistance level for any given position is the resistance level at the moment the stimulus in that position was presented. The graph of the mean resistance level against position is presented in Fig. 2.

By comparing this graph with that of the mean absolute deflections (Fig. 1) it may be noted that decrement in resistance level may accompany a decrement in the galvanic responses, but that the magnitude of the resistance level does not appear to be a factor in the galvanic response decrement. This is made apparent by the fact that at the beginning of Part II the galvanic responses suddenly increase greatly in magnitude and then adapt, whereas the resistance level,

although having a parallel decrement, decreases from the level at which it was at the end of Part I.

Further evidence that the resistance level is not a factor in galvanic response decrement may be found in those subjects showing an increase in resistance level during the course of the experiment. The mean deflection for each position was calculated for the twenty-eight fifteen-second subjects and for the twenty-two thirty-second subjects who showed an increasing resistance level during the course of the experiment. The graph of their mean absolute deflections against position is presented in Fig. 3. Although there is more variability

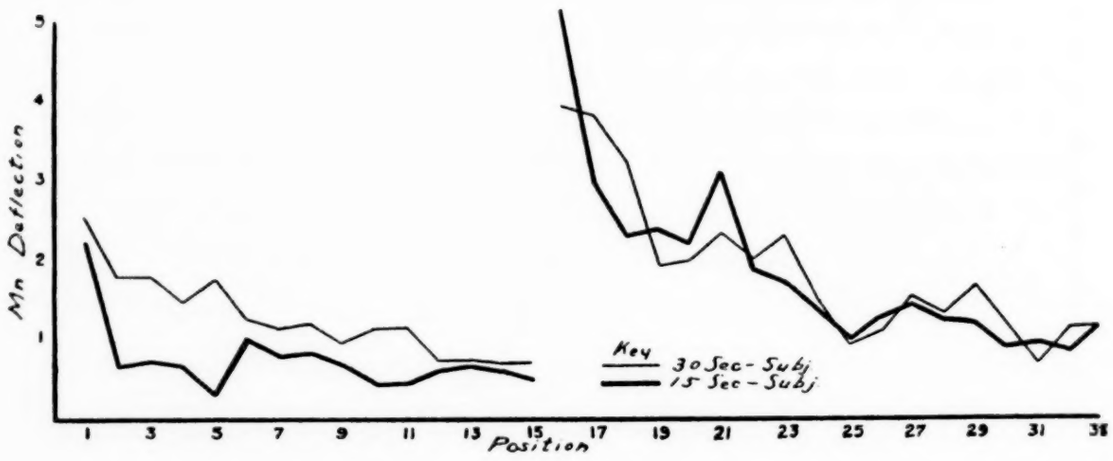

FIG. 3. Mean deflections of subjects with increasing resistance level.

due to the small number of subjects the trend of adaptation is apparent and closely parallels that for all the subjects (Fig. 1). However, it is possible that extremes of resistance level, particularly low resistance levels, may be a factor in galvanic response decrement.

D. Generality versus Specificity (Transfer)

Part II of this experiment employs six different stimuli, one following the other at thirty second intervals. These same six stimuli are then repeated in the same order for any given subject two more times, making eighteen stimuli which take positions sixteen to thirty-three. By rotating these stimuli, six different series are possible (*cf.* p. 249). At least thirty subjects were given each series. Half of these

subjects were thirty-second subjects, and half of them were fifteen-second subjects. As a result of this procedure, each of the six stimuli occurs in each of the eighteen positions and at least thirty subjects have a stimulus in that position.

This permitted the calculation of the mean deflection of each stimulus in each of these eighteen positions. All the stimuli except the phone show a decrement in galvanic response from positions sixteen to twenty-one. This despite the fact that a different group of subjects establishes the mean for each of the six positions of any one of the stimuli. This is clearly evidence that adaptation is in part, at least, general to the stimuli within a given sense modality.

To determine whether or not there was transfer of adaptation from one stimulus to another the following analysis was made. Subjects run on Series I (*cf.* p. 249) received the horn in positions sixteen, twenty-two, and twenty-eight. Series VI subjects received the horn in positions seventeen, twenty-three, and twenty-nine. Series V subjects received the horn in positions eighteen, twenty-four, and thirty, and so on. Now if adaptation is specific to a given stimulus then it should make no difference how many positions before the first horn are allocated to other stimuli. Further, the interval between any two horns is constant in duration for all series and constant in the nature and order of stimuli included within it. Hence the amount of adaptation during this interval, if adaptation is specific, should remain constant, despite a varying number of different stimuli that have been presented before the first horn. On the other hand, if adaptation is not specific but general, then the amount of adaptation during the interval between the first and any succeeding horn should be successively less for each additional stimulus (despite the fact that the stimulus is different from the horn) presented before the horn. This is only true if the rate of adaptation is decreasing. A glance at the curves of Fig. 1 show that the rate of adaptation is great at first and then slows down to a lower more or less constant rate.

This type of analysis and reasoning can be applied not only to the horn but to the other stimuli as well with the

exception of the phone. The phone had been presented in the first fifteen positions and had practically attained its maximum of adaptation. If adaptation were specific then the last two phones, each coming three minutes after the preceding with different stimuli presented in between at the usual thirty second intervals, should be unaffected by these different stimuli and would probably show some recovery during these comparatively long three-minute intervals. But if adaptation were general, then the stimuli presented in between should prevent recovery and deflections to the phone should remain at their low level or even decrease slightly in their magnitude.

The results of this analysis are presented in Tables III to VIII inclusive, each referring to a particular stimulus as designated.

The data presented in Tables III–VIII is further evidence that adaptation is to some extent general. For in the case of three of the stimuli: clapper, knocker, and gong, there are decreasing values in columns six and seven. This indicates that whether adaptation is measured in terms of absolute response decrement or in relative (percentage) terms, there is less adaptation between the first and third presentation of a stimulus if there have been more and different stimuli presented before the first presentation of the new stimulus. These same conclusions are borne out in the cases of the

KEY TO TABLES III TO VIII

Column I—Series; indicates the series from which the data in any given row was obtained.

Column II—*1st;* indicates the first time that particular stimulus was presented. Descending the column, the means refer respectively to the positions sixteen to twenty-one.

Column III—*3d;* indicates the third time that particular stimulus was presented to the group of subjects designated by the series number. Descending the column, the means are for positions twenty-eight to thirty-three respectively.

Column IV—*1st–3d;* difference between the mean deflections at first and third presentation. This gives the absolute amount of response decrement occurring during the six-minute interval between the first and third presentation of the stimulus.

Column V—Percent *1st–3d;* difference between the mean deflections at the first and third presentation divided by the mean deflection at the first presentation, expressed in percent. This gives the relative amount of response decrement during the six-minute interval.

Column VI—*Abs.;* the first figure in column six is an average of the first two figures in column four. The second figure in column six is an average of third and fourth figures in column four. And the third figure in column six is an average of the last two figures in column four.

Column VII—*Rel.;* the first figure in column seven is an average of the first two figures in column five. The second figure in column seven is an average of the third and fourth figures in column five. And the third figure in column seven is an average of the last two figures of column five.

TABLE III

SPECIFIC VERSUS GENERAL ADAPTATION

Horn

I	II	III	IV	V	VI	VII
Series	1st	3d	1st–3d	% 1st–3d	Abs.	Rel.
I	6.96	3.05	4.91	70.3	4.08	65.5
VI	5.33	2.09	3.24	60.8		
V	3.51	2.41	1.10	31.3	1.59	45.4
IV	3.48	1.41	2.07	59.5		
III	4.07	2.29	1.78	43.7	1.83	48.4
II	3.53	1.66	1.87	53.0		

TABLE IV

SPECIFIC VERSUS GENERAL ADAPTATION

Clapper

I	II	III	IV	V	VI	VII
Series	1st	3d	1st–3d	% 1st–3d	Abs.	Rel.
II	5.40	1.49	3.91	72.4	2.91	58.8
I	3.76	2.06	1.70	45.2		
VI	4.45	1.96	2.49	56.0	2.18	53.4
V	3.69	1.82	1.87	50.7		
IV	2.62	1.47	1.15	43.9	1.54	45.4
III	4.09	2.17	1.92	46.9		

TABLE V

SPECIFIC VERSUS GENERAL ADAPTATION

Phone

I	II	III	IV	V	VI	VII
Series	1st	3d	1st–3d	% 1st–3d	Abs.	Rel.
III	0.64	0.37	0.27	42.2	0.28	45.3
II	0.58	0.30	0.28	48.3		
I	0.99	0.39	0.06	60.6	0.48	49.5
VI	0.94	0.58	0.36	38.3		
V	0.63	0.34	0.29	46.0	0.39	52.2
IV	0.84	0.35	0.49	58.3		

TABLE VI

SPECIFIC VERSUS GENERAL ADAPTATION

Knocker

I	II	III	IV	V	VI	VII
Series	1st	3d	1st–3d	% 1st–3d	Abs.	Rel.
IV	3.40	1.12	2.28	67.1	2.51	69.2
III	3.85	1.11	2.74	71.2		
II	2.83	0.72	2.11	74.6	1.90	68.4
I	2.72	1.03	1.69	62.1		
VI	2.23	1.12	1.11	49.8	1.51	55.2
V	3.16	1.25	1.91	60.5		

TABLE VII

SPECIFIC VERSUS GENERAL ADAPTATION

Buzzer

I	II	III	IV	V	VI	VII
Series	1st	3d	1st–3d	% 1st–3d	Abs.	Rel.
V	5.65	1.73	3.92	69.4	2.96	66.2
IV	3.19	1.18	2.01	63.0		
III	4.35	1.29	3.08	70.3	2.64	68.6
II	3.36	1.15	2.21	66.8		
I	2.88	1.57	1.31	45.5	1.73	57.1
VI	3.13	0.98	2.15	68.7		

TABLE VIII

SPECIFIC VERSUS GENERAL ADAPTATION

Gong

I	II	III	IV	V	VI	VII
Series	1st	3d	1st–3d	% 1st–3d	Abs.	Rel.
VI	5.41	1.88	3.53	65.2	3.97	69.8
V	5.92	1.52	4.40	74.3		
IV	2.81	1.19	1.62	67.7	2.47	64.3
III	4.67	1.36	3.31	70.9		
II	3.07	0.69	2.18	71.0	1.88	60.5
I	3.08	1.51	1.57	50.0		

buzzer and horn but not so clearly as with the above three stimuli.

In the case of the phone the indications appear to be exactly the reverse. The stimulus here considered has been preceded in the first fifteen positions by the same stimulus. Yet when not given again until the eighteenth to twenty-first

position there is greater adaptation to it, both in absolute and relative terms, than if given in the sixteenth and seventeenth position. The simplest explanation is that when not given for an interval after the fifteenth position there is recovery, despite the fact that different stimuli are presented in the interval, and hence, as a result of the recovery, a greater degree of adaptation may take place. Whereas the phone in the sixteenth and seventeenth position has not had so much time for recovery to take place and hence there is less adaptation. These results on the phone indicate that adaptation is to some extent specific.

E. Startle and Affectivity in Their Relation to Galvanic Adaptation to Auditory Stimuli

For an indication as to the relation of the startle and the affectivity value of a stimulus to its galvanic adaptation, the following statistical procedure was used.

To obtain the amount of adaptation from positions sixteen to thirty-three individually for the six different stimuli presented in Part II, the difference between the mean deflection of the first three positions combined (16, 17, 18) and the mean deflection for the last three positions combined (31, 32, 33) was calculated and expressed both as an absolute difference in thousands of ohms and as a percentage of the mean deflection of the first three positions combined. The mean startle rating of each stimulus for the first three positions and the last three positions was calculated. The differences between the means for each stimulus was again expressed in terms of absolute difference between the mean ratings and percentage or relative difference.

The corresponding mean affectivity ratings were calculated and treated in a manner identical with mean startle ratings.

By combining three positions in this manner, the means are more reliable, being based on ninety cases. However, in comparing the first three positions of Part II with the last three positions, the comparison is made between two different groups of ninety subjects. It was important to determine if the relationships found by the above analysis also held when

the same subjects were used throughout. This was very readily carried out by simply substituting for the means (startle, affectivity, and galvanic response) of positions thirty-one, thirty-two, and thirty-three combined, the corresponding means for positions twenty-eight, twenty-nine, and thirty, which are based on the same subjects as the means for positions sixteen, seventeen, and eighteen. The results of this analysis are presented in Table IX *A* and *B*.

TABLE IX *A*

GALVANIC ADAPTATION IN RELATION TO STARTLE AND AFFECTIVITY

Position 16, 17, 18 to 31, 32, 33

Stimulus		Gong	Buzzer	Horn	Knocker	Clapper	Phone
Mn. Defl.	Pos. 16, 17, 18	4.71	4.30	5.49	3.32	4.53	0.74
Mn. Defl.	Pos. 31, 32, 33	1.26	1.23	1.78	1.13	1.81	0.42
Diff.		3.45	3.07	3.71	2.19	2.72	0.32
% Diff.		73	71	68	66	60	43
Mn. S.	Pos. 16, 17, 18	3.34	3.18	3.73	2.56	3.06	1.26
Mn. S.	Pos. 31, 32, 33	2.22	1.88	2.56	1.77	2.36	1.25
Diff.		1.12	1.30	1.17	0.79	0.70	0.01
% Diff.		34	41	31	31	23	01
Mn. A.	Pos. 16, 17, 18	4.66	4.53	5.67	3.34	4.37	3.95
Mn. A.	Pos. 31, 32, 33	4.33	4.29	5.22	3.15	3.89	3.86
Diff.		0.33	0.24	0.45	0.19	0.48	0.09
% Diff.		07	05	08	06	11	02

TABLE IX *B*

GALVANIC ADAPTATION IN RELATION TO STARTLE AND AFFECTIVITY

Positions 16, 17, 18 to 28, 29, 30

Stimulus		Knocker	Buzzer	Gong	Clapper	Horn	Phone		Phone 30 sec	Phone 15 sec
Mn. Defl.	Pos. 16, 17, 18	3.32	4.32	4.71	4.53	5.49	0.74	Pos. 1, 2, 3	2.16	1.78
Mn. Defl.	Pos. 28, 29, 30	0.98	1.40	1.53	1.83	2.18	0.36	Pos. 13, 14, 15	0.60	0.67
Diff.		2.34	2.90	3.18	2.70	3.31	0.38		1.56	1.11
% Diff.		70	67	68	60	60	51		72	62
Mn. S.	Pos. 16, 17, 18	2.56	3.18	3.34	3.06	3.73	1.26	Pos. 1, 2, 3	1.43	1.30
Mn. S.	Pos. 28, 29, 30	1.63	2.07	2.36	2.19	2.69	1.15	Pos. 13, 14, 15	1.21	1.23
Diff.		0.93	1.11	0.98	0.87	1.04	0.11		0.22	0.07
% Diff.		36	35	29	28	28	09		15	5
Mn. A.	Pos. 16, 17, 18	3.34	4.53	4.66	4.37	5.67	3.95	Pos. 1, 2, 3	4.03	3.97
Mn. A.	Pos. 28, 29, 30	3.11	4.17	4.31	3.87	5.33	3.69	Pos. 13, 14, 15	4.24	4.49
Diff.		0.23	0.36	0.35	0.50	0.34	0.26		−0.21	−0.52
% Diff.		07	08	08	11	06	07		−5	−13

It was felt desirable to see if a similar analysis on the phone, as given in Part I, would fit into these results on Part II.

As the phone was given in fifteen successive positions to the same subjects at thirty second intervals the results may only properly be compared with the data in Table IX *B* which is the adaptation of a group of subjects to specific stimuli over the same interval of time. The data on the phone as given in Part I to the fifteen-second subjects is included in the table but is not strictly comparable because of the different experimental conditions (the fifteen-second subjects have a higher rate of adaptation in the early positions due to the shorter interval between stimuli).

A summary of the relationships indicated in Table IX *A* and *B* are more clearly presented in Table X. The stimuli are here placed in rank order from highest to lowest score with respect to the statistic at the left of each row. The stimuli in Table IX *A* and *B* have been placed in order such that the one at the left of a row has the greatest relative galvanic adaptation and the one at the right the least.

There is very clearly indicated a relationship between the relative degree of galvanic adaptation to a stimulus and the relative degree of startle rating decrement of the stimulus, the stimulus with the greatest relative drop in mean startle rating also showing the greatest galvanic response decrement. The stimuli with intermediate degrees of relative decrement in mean startle rating have intermediate degrees of relative decrement in galvanic response in almost the same rank order. Another significant relationship indicated is that between the absolute degree of galvanic response decrement and the original mean startle rating of the stimulus. The stimulus with the greatest degree of galvanic response decrement has the highest original mean startle rating, and the remaining stimuli fall in the same order with respect to both mean startle rating and degree of absolute galvanic response decrement.

That there is a strong tendency for the stimulus with the highest mean startle rating to have the highest mean deflection

TABLE X *A*

GALVANIC ADAPTATION IN RELATION TO STARTLE AND AFFECTIVITY

Summary Table

Positions 16, 17, 18 to 31, 32, 33

Mn. Startle	Horn	Gong	Buzzer	Clapper	Knocker	Phone
Mn. Deflection	Horn	Gong	Clapper	Buzzer	Knocker	Phone
Abs. Galv. Decrement	Horn	Gong	Buzzer	Clapper	Knocker	Phone
Mn. Affectivity	Horn	Gong	Buzzer	Clapper	Phone	Knocker
% Startle Decrement	Buzzer	Gong	Horn	=Knocker	Clapper	Phone
% Galv. Decrement	Gong	Buzzer	Horn	Knocker	Clapper	Phone
Abs. Startle Decrement	Buzzer	Gong	Horn	Knocker	Clapper	Phone
Abs. Affec. Decrement	Clapper	Horn	Gong	Buzzer	Knocker	Phone
% Affec. Decrement	Clapper	Horn	Gong	Knocker	Buzzer	Phone

TABLE X *B*

GALVANIC ADAPTATION IN RELATION TO STARTLE AND AFFECTIVITY

Summary Table

Positions 16, 17, 18 to 28, 29, 30

Mn. Startle	Horn	Gong	Buzzer	Clapper	Knocker	Phone
Mn. Deflection	Horn	Gong	Clapper	Buzzer	Knocker	Phone
Abs. Galv. Decrement	Horn	Gong	Buzzer	Clapper	Knocker	Phone
Mn. Affectivity	Horn	Gong	Buzzer	Clapper	Phone	Knocker
% Startle Decrement	Knocker	Buzzer	Gong	Horn	=Clapper	Phone
% Galvanic Decrement	Knocker	Gong	Buzzer	Horn	=Clapper	Phone
Abs. Startle Decrement	Buzzer	Horn	Gong	Knocker	Clapper	Phone
Abs. Affec. Decrement	Clapper	Buzzer	Gong	Horn	Phone	Knocker
% Affec. Decrement	Clapper	Buzzer=Gong		Phone	=Knocker	Horn

and the largest amount of absolute response decrement is also apparent.

The mean affective rating of a stimulus shows some slight relationship with the mean deflection of the stimulus and the mean startle rating. More unpleasant stimuli tend to produce greater deflections and have a higher startle value. The change over the six minute interval in the mean affectivity rating of a stimulus appears to be independent of the mean affectivity rating, the mean startle rating, and the mean deflection, as well as the startle rating decrement and the galvanic response decrement.

Results of the similar analysis on the phone, as given in Part I to the thirty-second subjects, shows a higher degree of

relative adaptation, but not absolute adaptation, of the galvanic response than would be expected from the relative decrement of the mean startle rating. The significance of this will be considered later.

To bring out further the relationship between mean startle, mean deflection and mean affectivity of a stimulus these three means were calculated on fifteen-second subjects and thirty-second subjects combined; for each of the stimuli given in Part II the first, second, and third time the stimulus was presented. For example, the mean deflection for the first time the horn was presented (H_1) is based on the horn in positions sixteen to twenty-one, thirty subjects receiving the horn in each of those positions; the mean deflection for the second time the horn was given (H_2) is based on the horn in positions twenty-two to twenty-seven, thirty subjects receiving the horn in each of these positions. As a result, each mean is based on approximately 180 subjects, and the means for the first time the stimuli were presented (H_1, C_1, P_1, B_1, G_1) all have the same average position (approximately 18.5), similarly the means for the second time the stimuli were presented (H_2, C_2, P_2, K_2, B_2, G_2) all have the same average position (approximately 24.5), and the means for the third presentation of the stimuli (H_3, C_3, P_3, K_3, B_3, G_3) all have the same average position (approximately 30.5). Hence, for each of the three sets of six stimuli the position or adaptation factor is reduced to a minimum and the differences between the mean deflections of the stimuli within any one set may be attributed to other factors. Figures 5 and 6 are plots of the mean deflections of the stimuli against their mean startle and mean affectivity rating respectively. These plots show the relationship of the factors of startle and affectivity to absolute deflections. It may be seen from an inspection of these graphs that the relationship between startle and absolute deflections is definitely linear, and although not so clearly defined for the plot of affectivity and absolute deflections (Fig. 6) this relationship is probably linear also.

A side issue in these results, is the apparent increase in the unpleasantness of the phone as a result of repetition.

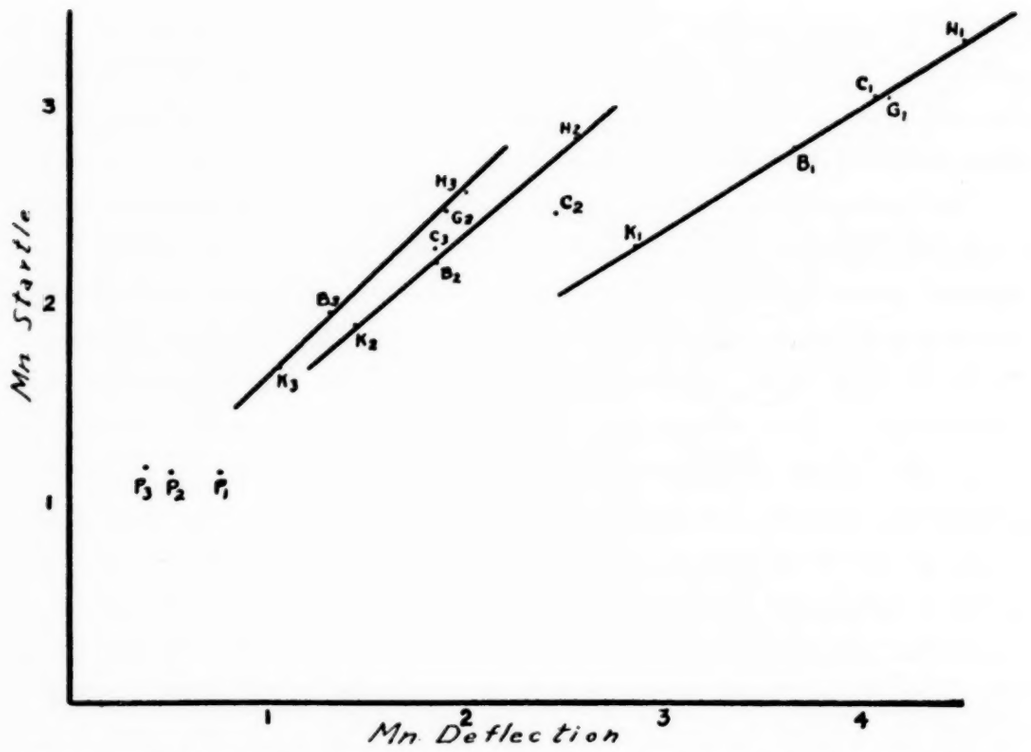

FIG. 4. Relation between mean deflection and mean startle 18 stimuli of Part II.

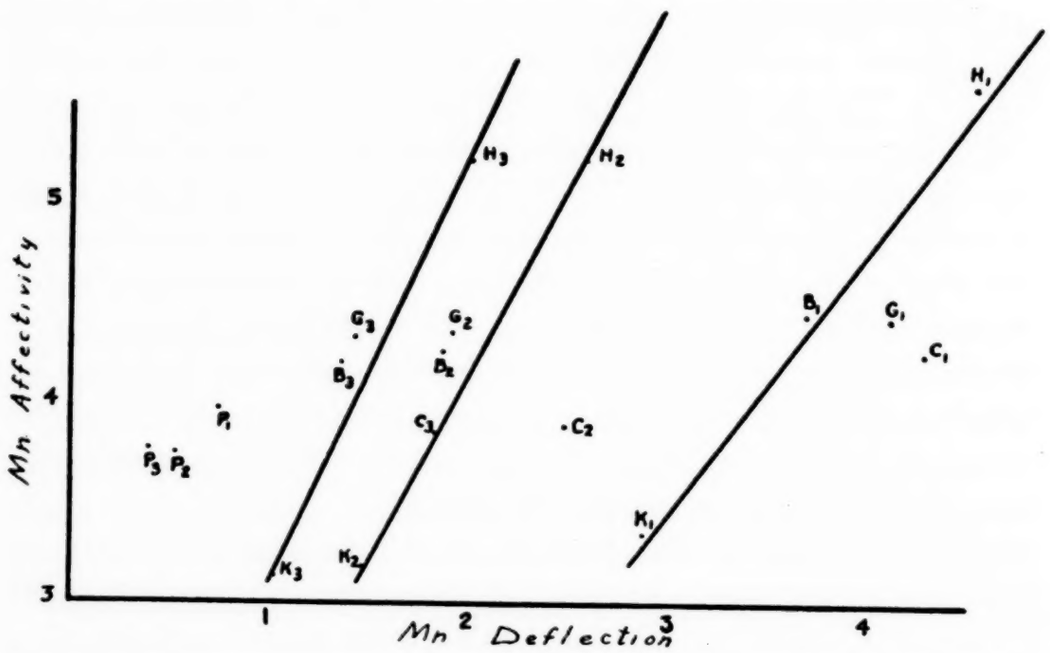

FIG. 5. Relation between mean deflection and mean affectivity 18 stimuli of Part II.

This may be seen graphically in Fig. 1 and numerically in Table IX *B*. The increase was greater for the phone given to fifteen-second subjects than when given to the thirty-second subjects.

IV. Discussion

The results of this experiment offer a certain amount of evidence for an hypothesis that there are both general and specific factors in galvanic adaptation to auditory stimuli. In addition to these factors there is another which must be taken into account in experiments of this nature. As shown by Landis and Hunt (**12**), "tension" is one of the outstanding correlates of the galvanic response. With naïve subjects, in the course of the experiment there occurs a general adjustment to the situation and a lessening of feelings of uneasiness which diminishes "tension," and, as a result, causes galvanic response decrement. This general adjustment to the situation, with its consequent lessening of "tension" explains the disproportionate degree of galvanic adaptation to the phone in Part I as compared with that occurring to the stimuli of Part II, as the "tension" aroused by the situation was probably reduced to a negligible factor by the time Part I was completed. As a result the major portion of adaptation occurring in Part II of the experiment is due to the general factor common to the six stimuli and to a slight extent (due to the three-minute interval between repetitions of the same stimulus) to the specific factors.

The general adaptation occurring in Part I is transferred to the various stimuli in Part II and to each one to an equal degree. Further adaptation to these specific stimuli then occurs in proportion as they possess this general attribute, which is a factor in the production of the galvanic response, and any possible specific attributes to which adaptation would not yet have occurred. As, for example, the stimuli are adapted to in proportion as they possess the attribute of startle. Startle, however, is complex and could perhaps be broken down into general and specific factors.

That galvanic adaptation to auditory stimuli is related to startle is established. However, the graphs of mean startle rating in Fig. 1 show that startle does not tell the whole story, for in Part I, particularly for fifteen-second subjects, mean startle ratings increase whereas galvanic response decrement continues. This would indicate that

factors other than startle and not controlled in this experiment also play a part in adaptation.

However, the rating scale technique for securing measures of startle and affectivity is not as accurate as would be desirable. It is probable that the subjects tend to maintain a rating once given, hence decrement in actual startle is covered up. Furthermore, it is possible that the subjects did not discriminate adequately between startle and affectivity ratings. However, the different results secured in the study of the relationship between deflections and startle as compared with deflections and affectivity, and also the difference in the trends of mean startle and mean affectivity ratings in Part I (*cf.* Fig. 1) speak for the independence of startle and affectivity ratings.

V. Summary and Conclusions

The experiment is divided into Parts I and II. Part I consisted of fifteen presentations of the same auditory stimulus. Part II comprised a group of six different auditory stimuli given in the same order three times for each subject. By rotating the group of six stimuli six different series were obtained. The subjects were 187 college women. For Part I they were divided into two groups. One group received all the fifteen presentations of the same stimulus at thirty second intervals. The other group received the first five stimuli at fifteen second intervals, and all the remaining at thirty second intervals. Both groups received all the stimuli of Part II at thirty second intervals. At least thirty subjects were run on each series in Part II; half of them were from the thirty second group of subjects and half from the fifteen second group of subjects. Startle and affectivity ratings were secured from each subject on each stimulus.

The conclusions may be briefly stated:

1. Galvanic adaptation proceeds rapidly at first and then slows down as the responses approach a more or less constant level.

2. Galvanic adaptation takes place more rapidly with a fifteen second interval than with a thirty second interval

between stimuli. But after the presentation of five stimuli, the significantly greater degree of adaptation of the fifteen-second subjects has no significant transfer effect on the remaining stimuli, all given at thirty second intervals.

3. With successive presentations of the same auditory stimulus there is a shift of the absolute affectivity value toward unpleasantness while the startle value shifts toward "no startle" at first and then appears to creep back a little.

4. A relationship is established between the mean startle rating of a stimulus, its mean deflection, and its absolute response decrement.

5. A relationship is established between the relative mean startle decrement of a stimulus and the relative response decrement.

6. The mean affectivity rating of a stimulus appears to be related to the mean startle rating.

7. There is no relationship between the changes in affectivity upon repeated presentations and the concomitant changes in mean startle rating and galvanic response.

8. Absolute startle decrement appears to bear no consistent relationship with any of the other measures.

9. With the position factor held constant the magnitude of the galvanic deflections to auditory stimuli bears a linear relationship to the mean startle rating and perhaps also to the mean affectivity rating (on the "unpleasant" side of "indifference").

10. Evidence is offered that galvanic adaptation to auditory stimuli is in part general and in part specific to the stimulus. An hypothesis is presented as to the nature of the factors underlying transfer of adaptation.

11. Changes in resistance level appear to be unrelated to galvanic response decrement.

(Manuscript received September 29, 1937)

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THE EFFECT OF TACTILE STIMULATION UPON THE BERGER RHYTHM

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This study concerns the effect of tactile stimulation on the alpha or Berger rhythm, in relation to both latency and perserveration time. Latency is defined as the length of time between the application of the stimulus and the obliteration or marked depression of the alpha waves. Perseveration is the length of time elapsing between the removal of the stimulus and the complete return of the alpha rhythm (Fig. 1).

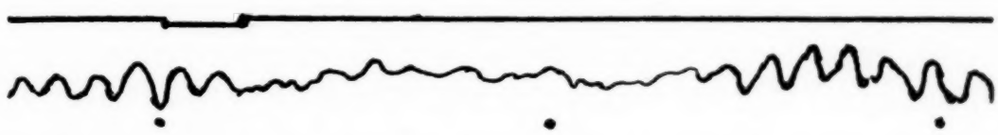

FIG. 1. Record showing depression of Berger rhythm from tactile stimulation of eyelid and the re-establishment of the rhythm following cessation of stimulation. Displacement of signal line at top gives duration of stimulation. Time intervals in sec. marked off at bottom. In this record, latency read as 0.30 sec. and perseveration time as 1.37 sec.

For recording brain potentials a three stage resistance-capacitance coupled amplifier driving a special four tube matching amplifier was used to activate a Boehme type 2-A undulator (ink-writing). The equipment gave a uniform response from 1 to 30 ~ per sec. The potentials were led off by means of plate electrodes, one placed on the scalp at a position about one inch above and one inch to the left of the occipital protuberance, and the other on the lobe of the left ear.

The subjects were placed in a dark and semi-soundproofed room, lying comfortably on a cot with the eyes closed. They were also blindfolded. Two kinds of stimulus, a blunt and a sharp, were used. The blunt stimulus was the flat end of a cylindrical rod somewhat smaller than a common lead pencil. The sharp stimulus was the blunt end of a phonograph

needle. Stimuli were applied to three areas of the body: the forehead, the eyelid, and the shin about three inches above the ankle. The subjects were informed of the nature of the stimulus and were urged to remain passive to the stimulations. For the blunt stimulus there were approximately 24, and for the sharp approximately 29 grams pressure.

From the seven adult subjects 2,542 records were obtained. Of this number 1,457 (56 percent) were legible, the remainder having been discarded because of technical inadequacies (such as blocking of amplifiers at time of application of stimulus, or application of the stimulus when the waves were absent) or because the change in the brain potentials was so gradual or so capricious as to be impossible to read accurately for latency and perseveration time. However, very few records were discarded in which the waves were present at the application of the stimulus. In the great majority of the legible records (70 percent) the stimuli were ineffective, that is, the alpha rhythm was either not affected at all or the waves became even larger at the time of stimulus application or immediately thereafter. Table I gives the number of legible records for each series and the percentage of records in which the stimuli were effective.

TABLE I

PERCENTAGE OF RECORDS IN WHICH STIMULI WERE EFFECTIVE

Series	No. of Legible Records	Percentage Affected
Blunt Forehead	221	39
Blunt Eyelid	220	33
Blunt Shin	264	32
Sharp Forehead	246	31
Sharp Eyelid	228	26
Sharp Shin	278	20
Total	1,457	30

The results of an unpublished study by Martinson from this laboratory dealing with the effect of visual and auditory stimulation on brain waves, show that all light but not all tone stimulations affect the waves. The louder tone (70 db) affected the waves in 44 percent of the legible records, and the softer tone (40 db) in 36 percent of the readable records. Thus it appears that so far as these studies go, visual stimuli are the most, and tactile stimuli the least, effective.

In several records of the present study the stimulations were undoubtedly effective, but the latency was relatively too long to be attributed to the stimulus itself. In almost all of these instances the perseveration time was either extremely long (as great as nine sec.) or the behavior of the waves was such that the perseveration time could not be accurately determined. The exceedingly long perseveration times might have been due to the stimulus producing some train of associations or a disturbing feeling tone.

For all series the mean latency was 0.48 sec. and the mean perseveration time, 1.08 sec. (Table II). It will be

TABLE II

MEAN, RANGE, AND S. D. FOR LATENCY AND PERSEVERATION TIME FOR EACH SERIES OF STIMULATIONS

Series	Latency				Perseveration			
	N	Mean	Range	S.D.	*N*	Mean	Range	S.D.
Blunt Forehead.....	87	.46	.17–1.10	.21	79	1.26	.17–5.05	.88
Blunt Eyelid.....	68	.48	.17–1.15	.24	71	1.12	.20–4.07	.76
Blunt Shin.....	84	.52	.22–1.10	.22	75	1.02	.20–3.45	.60
Sharp Forehead.....	73	.46	.17–1.05	.24	72	.97	.17–5.15	.73
Sharp Eyelid.....	60	.40	.17–1.27	.22	56	1.16	.30–8.60	1.22
Sharp Shin.....	55	.53	.18–1.17	.24	53	1.12	.32–4.45	.80
Total.....	427	.48			406	1.08		

noted that the number of records does not correspond for latency and perseveration time in the same series. This is so because some records could be clearly read for latency but not for perseveration time, and vice versa.

In undertaking this study it was thought that there might be a difference in latency for such widely separated areas as the head and the shin. Accordingly, critical ratios for mean differences in latency were calculated for several pairs of series. In one pair only, sharp eyelid and sharp shin, was there found a statistically significant mean difference (CR 3.1).

Several studies, notably those of Berger,[1] Loomis, Harvey, and Hobart,[2] and Travis, Knott, and Griffith[3] report for

[1] Berger, H., Ueber das Electrenkephalogramm des Menschen. *Arch. f. Psychiat. u. Nervenkrank.*, 1932, **97**, 6–26.

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light a brain wave latency of approximately 0.20 sec. and a perseveration time of approximately 1.0 sec. As Jasper [4] has pointed out, both latency and perseveration time vary with intensity of the light; the stronger the light, the shorter the latency period and the longer the perseveration time. For progressively decreasing light intensities he reports latencies ranging from 0.12 to 0.92 sec. with corresponding perseveration times from 3.9 to 1.3 sec. Durup and Fessard [5] also report latencies for light stimuli of diminishing intensities, the latencies ranging from 0.17 sec. to 0.36 sec.

For auditory stimulation Martinson found a latency period of approximately 0.3 sec. and perseveration time of approximately 1.4 sec. Latencies to sound stimuli of 0.35 sec. to 0.50 sec. were reported by Durup and Fessard. They called attention to the fact that the latency period for sound stimulation was greater than that for light.

Since it is difficult to equate intensity of stimuli in the different sense modalities and since the studies reported made no attempt to do this, it is impossible to state definitely that stimulation in any one sense modality produces greater effects than would equivalent stimuli in the others. However, from the available data it appears that light stimuli produce effects of the greatest magnitude while tactile stimulation produce effects of the least magnitude. That is, for light stimuli are found the shortest latencies and the longest perseveration times, while for tactile stimulation are found the longest latencies and the shortest perseveration times. With respect to the relative effectiveness of the stimuli, that is, in producing any determinable effect at all, the three sense modalities seem to rank in the same order as for relative magnitude of the effect, namely, vision, hearing, and touch.

(Manuscript received October 11, 1937)

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THE UPPER LIMIT OF CUTANEOUS SENSITIVITY TO FREQUENCY OF VIBRATION IN THE WHITE RAT *

BY ALEC SKOLNICK

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The response of the sense of touch to frequency of vibration has been investigated in man by many workers. It would be advantageous for further work on physiological lines to study this response in lower animal forms, where relatively few investigations have been made.[1] Therefore, this preliminary study of the upper limit of the vibratory sense in the white rat was undertaken.

Four rats were trained to choose between a vibrating and a non-vibrating platform. The animal was placed upon a third platform, the starting base, from which it could cross to either of the other platforms by reaching over a gap. The arrangement of these platforms is shown in Fig. 1. The choice-platforms were placed diagonally to the starting base. At the end near the starting base, the choice-platforms were separated by 2½ inches. At the farther end, the choice-platforms were separated by 5½ inches. The distance between the starting base and the choice-platforms was varied from 4 to 6 inches according to the size of the animal, to permit it to bridge the gap comfortably. This arrangement made it possible for the animal to place a fore-paw upon each of the choice-platforms simultaneously, in order to determine which one was vibrating. However, the usual procedure adopted by the rat was to make contact with the choice-platforms in alternation before crossing.

The starting base was a board 9 × 4 inches mounted at a height of 16 inches above a table. The two choice-platforms were made of 3-ply veneer board (8½ × 4¾ × ⅜ inches) mounted upon ringstands at the same level as the starting base. Each choice-platform was attached, by means of a small rod, to a magnetic loud-speaker motor. The amplified output of a 2-A audiometer set either of the loud-speaker motors vibrating at a given frequency, and this vibration was transmitted through the rod to the choice-platform. The audiometer was modified, by the addition of condensers, to

* From the Psychological Laboratory of Princeton University.

[1] Studies of the response to vibration of certain animal forms have been made by the following: Rode (7) showed that fish with free sensory organs at the surface of the skin perceive vibrations. Verrier (10) after observing the behavior of Typhlichthys Osborni Eigenmann, declared that the behavior of this fish is dominated by its vibratory sense. Grünbaum (4) studied the orientation of the spider to vibration. Responses to vibratory stimuli through the frequency range from 50 to 300 cycles were developed in the dog by Southerland and Dworkin (8). None of these investigations was concerned with the limits of the vibratory sensitivity of the animal studied.

produce not only the octave tones between 256 and 2048 cycles, but also frequencies from 1100 to 2000 cycles, and from 2300 to 2500 cycles, in steps of 100 cycles.

Training was started at 256 cycles. Two animals (males) were required to choose the vibrating platform, while the other two (females) were required to choose the non-vibrating platform. A correct choice was rewarded with food; an incorrect choice was punished by a tap on the nose with a pencil. The choice was not considered complete until all four of the animal's feet were upon one choice-platform. Then the animal received its reward or punishment. Higher frequencies were introduced as soon as the animals showed performances of 70 percent correct or better. The animals were run ten trials daily at a given frequency. Progressive improvement in the accuracy of performance was shown by the rats up to 1800 cycles. Then at higher frequencies, the behavior of the females (who were running at higher frequencies than the males, due to more rapid learning) showed signs of disorganization. The procedure for all the animals was, therefore, modified. Every day, each animal was started upon the highest frequency that it had last performed with 100 percent accuracy. The animal was continued through a series of progressively higher frequencies, ten trials

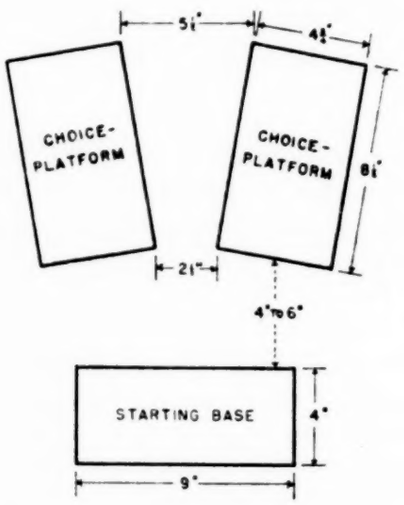

FIG. 1.

at each, until its performance dropped to chance. This was determined not only by the number of errors the rat made, but also by observation of its marked hesitation and uncertainty.

The following checks for secondary cues were made. The rats were blinded to eliminate visual cues. Olfaction was controlled by feeding the animal after it had made a correct crossing. Since the tones produced by the vibrating platforms could not be eliminated, a masking tone was introduced in the later stages of the experiment as a test for auditory cues. No change in performance was observed. That the animal received cues through bone conduction is a possibility, but it seems highly improbable for the following reasons. First, the masking tone would diminish cues through bone conduction. Second, the threshold value obtained is much below the upper limit of hearing in the rat.

The results are shown in Fig. 2. For the frequencies below 1400 cycles the data are not plotted, since they merely showed a curve of learning. From the results for 1400 through 1700 eycles, ti is apparent that thc animals had

learned to discriminate between the vibrating and the non-vibrating choice-platforms with a high degree of accuracy. Then the curves show a falling off in accuracy of performance until chance performances appear at 2400 cycles for two rats, and at 2500 cycles for the other two.

We take as an indication of the upper limit a performance that is 75 percent correct, since this value is midway between perfect and chance discrimination. The upper limit of the vibratory sense of these rats is then in the vicinity of 1800–

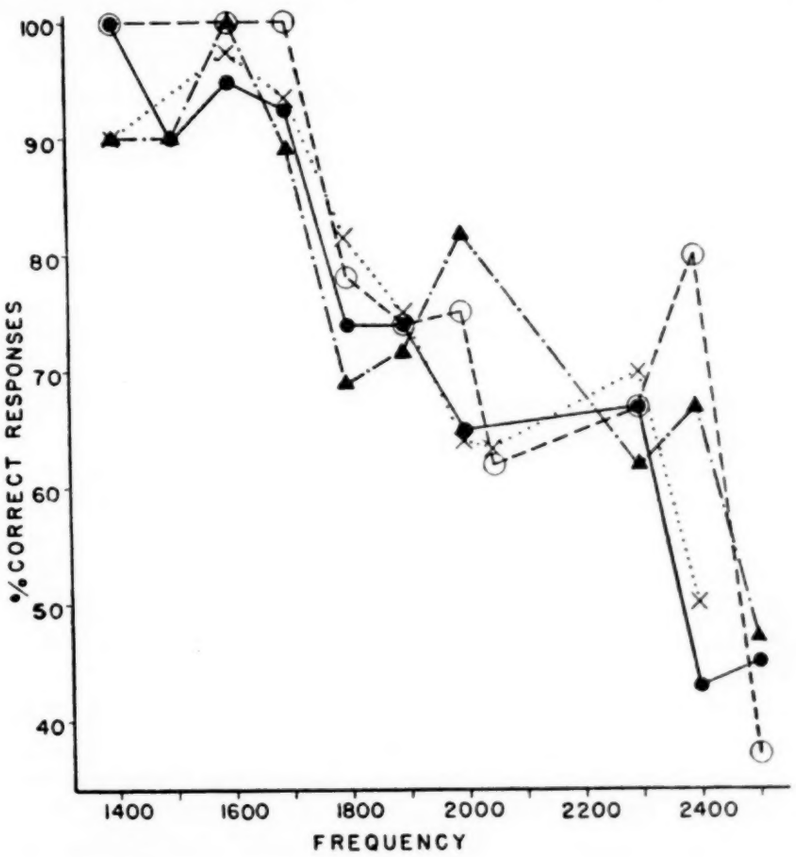

FIG. 2.

2000 cycles. However, it must be remembered that this result, to some extent, depends on the apparatus used. Knudsen (4), working with human subjects, has shown that the upper limit is a function of amplitude. In this study of the rat, amplitude was not controlled. But Knudsen has also shown that sensitivity in man is a function of frequency; sensitivity is maximal at 256 cycles, and decreases rapidly for higher frequencies. It would seem then that the upper limit of the rat is not likely to be much higher than the value obtained.

Comparison of these results on the rat with those obtained by other investigators on man is difficult, since the thresholds for man previously reported in the literature vary widely.[2] Therefore, the upper limit for the finger-tips of 8 human subjects was determined with the same apparatus that had been used for the rats. None of the human subjects was able to sense 1800 cycles. Five were able to feel 1700 cycles, and all could easily feel 1600 cycles.[3]

It is concluded that the upper limit of cutaneous sensitivity of the white rat to frequency of vibration is about 1800–2000 cycles. The results obtained from the rats correspond closely with those from human subjects with the same apparatus.

(Manuscript received October 17, 1937)

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[2] The values for the upper limit of the vibratory sense in human subjects as determined by different workers are:

528 cycles, Thiel (9)
1300 cycles, Kampik (5)
1600 cycles, Knudsen (6)
2600 cycles, Gilmer (2)
3000 cycles, Gault (1)
8192 cycles, Goodfellow (3).

[3] The vibration rate, 1600 cycles, was apparently more intense than several of its neighboring frequencies. One of the human subjects, though he could feel 1600 cycles easily, was unable to feel 1400 or 1500 cycles. The records of the performances of the rats at 1600 cycles also show that this frequency was easily discriminated.

THE REACTION TIME TO VESTIBULAR STIMULI

BY BRENT BAXTER AND ROLAND C. TRAVIS

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Introduction

Many studies have been made in the determination of reaction times in various sense modalities during the last forty years. It would be superfluous to review the results of all these studies in this brief experimental report. Therefore brief summaries of simple and choice reaction times reported by Garrett (1), from the works of Henmon and Cattell will be presented for the purpose of comparison with the much longer reaction times of the vestibular system in the perception of motion.

Table I gives the simple and choice reaction times of several modalities which have been reported in the literature, together with the vestibular reaction time obtained in the present study.

TABLE I

Modality	Reaction Time	Discrimination Time
Visual	.150– .200 sec.	.197
Auditory	.120– .160 sec.	.290
Tactual	.110– .160 sec.	
Olfactory	.200– .800 sec.	
Gustatory	.300–1.000 sec.	
Pain	.400–1.000 sec.	
Temperature		
Cold about	.150 sec.	
Warm about	.180 sec.	
Vestibular (Baxter and Travis—this study)		.598

Cattell found that the discrimination times were longer, depending upon the complexity of the discrimination. He also noted a similar increase due to choice in reacting. Increases in the reaction times as a result of discrimination and choice varied between about .002 second and .101 second, depending upon the task. Henmon found the discrimination time for black and white and color to be from .197 second to

.271 second and for small differences in pitch from .290 to .334 second.

The present problem was to determine the reaction time of voluntary response to the perception of passive rotary motion of the body with visual and auditory cues either removed or masked. Several technical difficulties peculiar to the vestibular system and in the perception of bodily motion presented themselves. One problem was the presentation of adequate stimuli for the arousal of the vestibular system with other sensory cues eliminated or reduced to a minimum. It was necessary to have the intensity of the stimulus above the threshold but not great enough to stimulate other receptors. A further complication was the inability to localize consciously the source of sensory stimulation in the perception of passive bodily motion. We assumed, however, that the vestibular system including the semicircular canals were the receptors for the passive bodily motion of the character we used in this study.

Method and Procedure

The general experimental apparatus was a chair mounted on a rotation-platform which in turn was mounted on a ball-bearing base. The platform was further supported overhead by a tripod arrangement. The essential features of this apparatus were similar to those used by Travis and Dodge (2). Vibrations in the chair during rotation were negligible, and according to introspective reports did not excite tactual or kinaesthetic receptors.

The subject was seated comfortably in the chair with his head supported in a head-rest so that the axis of rotation passed vertically between the right and left semicircular canals. The platform was driven by means of a crank and pulley attached at a point one-hundred cms. from the axis, and oscillated 2 degrees in 1.29 seconds. The rapidity of this movement was well above the threshold of the vestibular system as found by Travis and Dodge (2) in a previous report. A simple device for stopping the chair at the end of an oscillation (which was the same as the beginning of an oscillation) without stopping the motor was arranged. The stimulus hereby offered was continuous and intermittent passive rotary oscillation of the subject to the right and left.

The subject responded by the pressure of either his right or left thumb upon one of two telegraph keys, according to whether he perceived motion to the right or to the left.

Recording was by means of a double-unit marker with a single point upon the smoked drum of a spiral kymograph. As soon as the chair began to move in either direction, one unit moved the marker to the left. Pressure upon the telegraph keys caused the second unit to move the marker to the right. The marks made by the oscillation of the chair signified alternate movements to the left and right, but there

was no means of telling whether or not the subject responded by the correct manual discrimination other than as the experimenter noted. However, as the movement was supraliminal, no subject reported any difficulty in discriminating direction.

A Becker marker in circuit with a 60-cycle, 110-volt alternating current transformer made one-hundred-twenty marks per second in a line adjacent to the reaction line. In as much as the kymograph was driven by a synchronous motor, it was necessary to measure only the distance on the record between the initiation of the movement of the platform and the response of the subject. Checking of each record in at least two places revealed that fifty millimeters equaled sixty one-hundred-twentieths of a second. As a result the distance, measured in millimeters, gave the time in hundredths of a second.

Before each experiment the subject was given preliminary instructions and a few trial reactions so that he understood his task. The emphasis was placed upon the necessity of speed in his reaction rather than the discrimination between right and left. The subject was then blindfolded, and the recording apparatus was started which masked any possible auditory cues. The subject was told to react as soon as he felt any motion. After a pause of a second or two, the chair began to oscillate. The duration of each experiment was about four minutes. Sometimes the chair changed directions without stopping, and these stimuli were designated as continuous. When the chair moved from a dead stop, the stimuli were termed discrete. The continuous and discrete stimuli were presented in random order so that the subject never knew which was coming next.

The subjects were all students in psychology and were thus familiar with the meaning of reaction time. Nine of the men subjects had taken reaction time tests in other modalities. The authors were included as subjects.

Results

The average time for the reactions to the movement of 2 degrees in 1.29 seconds was 0.598 second for 31 subjects. Figure I shows the distribution of 1,279 reactions of the 31 subjects. The total range was from 0.190 second to 1.790 seconds with a standard deviation of 0.243 second. It will be noted that the curve is skewed to the left. This skewness is much greater than that found for other modalities.

As compared to the other more important modalities such as vision and audition, where the reaction times are between 0.120 and 0.200 second, the vestibular reaction time is about three times as long. This difference is probably not so much due to the fact that the subject had to discriminate between right and left movement and respond by a choice of two keys, as to the nature of the receptor. The discrimination between right and left was of the most elementary type in which the problem of threshold did not enter. Thus the slowness of the reaction was probably not due to the complexity of the

discrimination-choice problem presented. Rather there appears to be a correlation between the nature of the physical excitation of the receptor and the speed of reaction.

In preliminary experiments it was noted that there was a difference in the length of the reaction time to successive

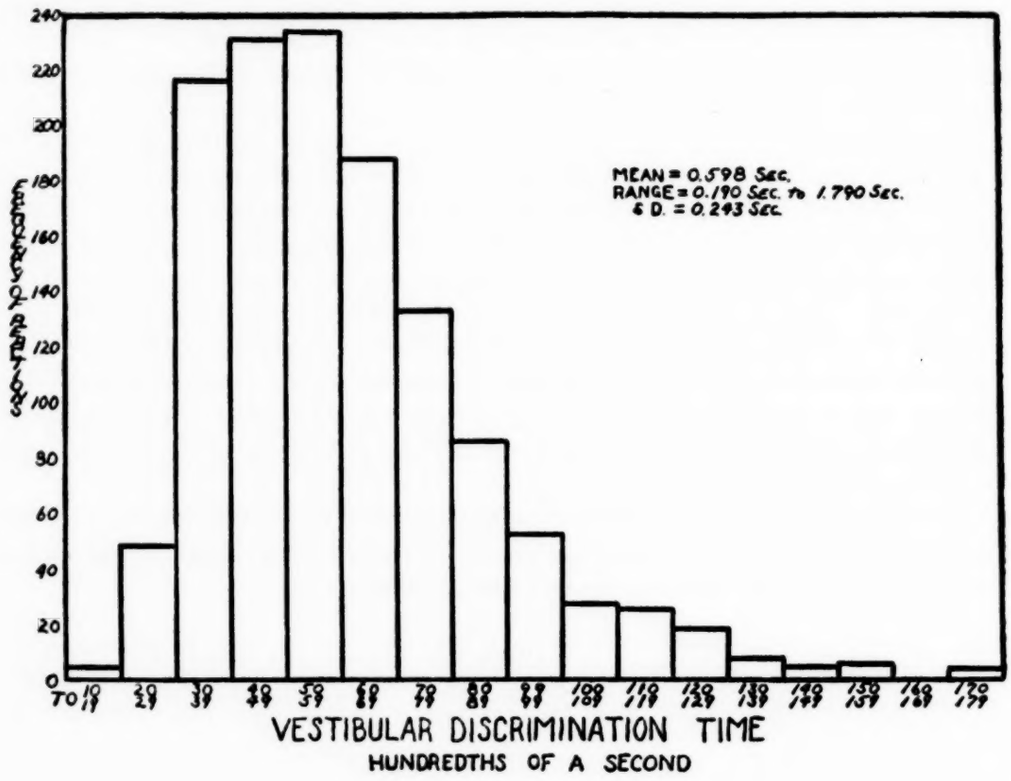
MEAN = 0.598 Sec.
RANGE = 0.190 Sec. to 1.790 Sec.
S.D. = 0.243 Sec.
FREQUENCY OF REACTIONS
VESTIBULAR DISCRIMINATION TIME
HUNDREDTHS OF A SECOND

FIG. 1.

oscillations as compared to discrete right and left movements of the platform. This difference was found to be reliable upon examination of the data from the main experiment shown in Table II. The mean reaction time to successive oscillations was 0.722 second; the mean reaction time to discrete movements was 0.516 second. The actual difference

TABLE II

Type	Number of Reactions	Mean	Range	S.D.	S.E.m	C.R.
Total	1729	.598	.190–1.790	.243		
Discrete	773	.516	.190–1.450	.208	.0075	
Continuous	506	.722	.240–1.790	.239	.0106	15.9

of these means was more than fifteen times as great as the standard error of the difference of the means, a highly significant difference.

It appears that in the vestibular system the physical factors of momentum and inertia are very important. The liquid in the semicircular canals is more disturbed while in motion than when in a state comparable to rest. These results suggest the problem of the length of time necessary for the liquid of the ear following excitation to again reach an optimum point of equilibrium ready for stimulation.

The average score for the reaction time to the left was found to be 0.599 second and to the right, 0.597 second. All our subjects reported that they were right-handed. Since Cattell (**3**) and others have found that the reaction times for the two hands are approximately the same (the right hand between one and three milliseconds faster than the left), it appears that the excitability of the right and left semicircular canals are about equal, assuming that the canals on one side function predominantly in the perception of motion in that direction. We have no direct evidence to support this statement.

The average score for the men (23) was found to be 0.587 second, and for the women (8), 0.633 second. Since the number of cases of men and women were so small and unequal, this difference is not statistically reliable, though it seems to further substantiate similar results found in other modalities, that reaction times are somewhat shorter for men than women.

Four of the subjects (three men and one woman) repeated the experiment. Their average scores for these trials are shown in Table III. The average gain was only 0.012 second

TABLE III

Trial	MJT	FHL	PR	RW
1	.504	.536	.375	.516
2	.515	.478	.370	.522

on the second trial. It is evident that there was little or no improvement made on the second trial, and in two cases there was even a slight increase in the reaction times.

Out of 1319 stimuli there were only 40 failures to respond, or about one failure to respond upon each subject's record. Since there were so few failures to respond and only two anticipatory responses, there is evidence that the speed of the chair was at an highly advantageous rate for this experiment. Almost three times as many (29 to 11) of the failures to respond were to successive stimuli than to discrete stimuli. This would seem to substantiate our belief that the semicircular canals must be at rest, or nearly so, to be in the condition of greatest excitability.

Summary of Results

1. The average vestibular reaction time to passive bodily motion was 0.598 second ranging from 0.190 to 1.79 second.

2. The reaction time to successive oscillations was reliably slower than the reaction time to discrete movements, probably due to the peculiarities of the vestibular system.

3. The reaction time to the left was 0.002 second slower than the reaction time to the right (.599 to .597), which was not significant.

4. The reaction time for men appeared to be shorter than that for women, though our results are not statistically significant.

(Manuscript received September 27, 1937)

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THE BLIND HAVE "OPTICAL ILLUSIONS"

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It has been known for some time that a fruitful approach to the problem of perception is through studies of illusions. This is due, of course, to the fact that discovery of anything that prevents a group of these misperceptions from becoming true percepts reveals a necessary factor in efficient perceiving in that field.

The justification of this study of the reactions of the blind to illusion patterns is that their active touch behavior in perceiving is more objective and can be observed in greater detail.

Twenty-eight totally blind persons were found in the Louisiana School for the blind and in the University who could be available for this research, and one who, on rare occasions, was able to see uncertainly one edge of an object when there was a strong light on the opposite side of it. All but three had been blind from birth. One of these had normal sight one year, another two years, and a very bright eleven-year-old girl was deprived of her sight at nine, when she was operated on for a brain tumor.

The ages of nine of these blind subjects ranged from seven to eleven years, eight of them from twelve to fifteen years, six from sixteen to nineteen years, and five between twenty and twenty-six years of age.

Twenty-eight persons, with corresponding numbers in these four age levels, were selected for the visual group from the practice school, the colleges, and the graduate school of Louisiana State University.

The individuals were matched in the relative quality of their school work, but not in intelligence quotients, because the tests for the blind are thus far insufficiently standardized.

Both were experimental groups for comparison of their behavior rather than an experimental and a control group except in so far as this end was served by subsequent presentation of the same patterns to the sight of the visuals.

The graduate student was the only observer who had any knowledge of illusions.

Six well-known patterns of unlike types were used, the Müller-Lyer, the horizontal-vertical, the Poggendorff, the two equal circles within an acute angle, the Zöllner, and the two segments of a ring. These figures were mounted in relief on veneer-ply boards. The linear patterns were made of wire twelve-hundredths of an inch in diameter and the surfaces were cut out of thick sheet aluminum of similar thickness.

The patterns were large enough to require active exploration, a much more usual way of sense-perceiving objects and spaces than passive reception of pressure stmiulation. The pressure of small patterns on the hand was the method employed by Révész[1]. His blind and visuals got a wide variety of illusions.

In order to obviate suggestion, which leads to expectation and preparatory set and were doubtless factors in the experiments of Révész, I made each pattern in several sizes, with the primary dimensions equal and unequal. These were presented in unpredictable order.

The experimenter sat at one end and the observer at the other of a table. A canvas hood helped to conceal from sight the stimuli not in use and the one being examined by the subject. The leaves of the table in vertical position, the hood and the screen were used with the fifty-six subjects, blind and seeing. Several very active children looked under the hood before directions could be given. This justified the use of a one-way screen in addition to the hood.

After a stimulus board had been slid beyond the screen to cleets that held it firmly within equally easy reach of either of the reagents' hands, he was told to explore it thoroughly with his preferred hand until he was sure of the decision that he was required to make.

As was expected, perception through active touch exhibited the process of perceiving in a much more obvious, objective form than perception through sight and is freer from disturbing factors in the technique.

Every blind and visual reagent seemed to find the short lines of the Zöllner illusion serious obstacles to progress back and forth on the long lines from the beginning of inspection to the slowly-reached conclusion. The lines seemed longer than they were.

After the first rapid survey of the horizontal-vertical pattern, the fingers of the observers who experienced the illusion went from end to end of the horizontal line, but

[1] Révész, G., System der optischen und haptischen Raumtäuschungen. *Zeits. f. Psychol.*, 1934, 131, 296–375.

strangely failed to go to the top of the vertical line. The illusion was usually greater when the vertical line extended upwards from the horizontal line than when it extended downwards, and was more often and more promptly reported.

Inspection of the Poggendorff pattern consisted of the following of the line to the vertical column, indications of confusion, then ascending and descending along its two edges several times, fumbling for the other line, and slowly overcoming the difficulties in finding the other portion of the line. The decision was not rendered by those who got this illusion until the fingers succeeded in slowly following what seems to be an imaginary line across the column from the entrance of the line to its exit.

On the Müller-Lyer pattern the last part of the systematic procedure was a to-and-fro motion. The fingers never went beyond the ends of the line with feather-like trimmings. But they almost always stopped short of the ends of the line with arrowheads, and when they did go, to the ends, they moved as mine would if I were interested in the angular spaces between one line of the arrowhead and the main line.

Comparison of the two equal circles was made most consistently by tracing only part of each circumference, then of the spaces between each circle and the lines of the angle. The widths of the ring segments were quickly declared by all to be equal after sliding the hand across the one and the other. Comparison of their lengths was much slower, and judgment was very often made just after the handling of the sides of the two figures that were closest to each other. There was a tendency, after a corner or two had been turned in a ring segment, to move erringly along the lines as though they were expected to be straight like the sides of a rectangle. Usually a finger could not remain on a curved line without the help of the thumb on its opposite side. In these reactions to the sectors of a ring, decisions were immediate when the fingers found the two unequal adjacent lines. In the vertical-horizontal figure pains were not taken to go to the top of the vertical one, but only far enough to detect its apparent greater length.

A standard pattern either gave an observer an illusion every time, or nearly every time, that he was given an opportunity for his hand to explore it or else his responses were totally irregular. There was in no case any discoverable inclination towards correct perception instead of illusory perception.

Consistent, repeated responses showed that the Müller-Lyer illusion was experienced by 24 blind and by 2 visuals; the Poggendorff by 22 blind and 4 visuals; the vertical-horizontal by 22 blind and 3 visuals; the circles in the angle by 12 blind and no visuals; the Zöllner by 10 blind and no visuals; and the ring segments by 7 blind and 2 visuals.

In the blind group, the dull eight-year-old girl gave totally inconsistent reports and the very dull seventeen-year-old boy responded definitely to the Müller-Lyer illusion, but to no other. In general, in the blind group and the seeing group the brighter the observers the more illusions they had. The total percent of illusion reactions by the blind children who were seven to nine years old was 57; by those who were eleven, 72; by twelve to fourteen-year-old youths, 55; by fifteen-year-olds, 57; sixteens, 62 and nineteens, 72. The two blind college students and one graduate experienced 72 percent. The eleven-year-old children were on a par with the blind who were nineteen and older, partly because of the bright girl who had normal sight until she was nine years old.

All of the visuals, except the two dullest, when finally permitted to use sight, experienced illusions with every standard pattern. Striking differences were found in those who had many illusions and those who had few. The reagents who had many waited to hear all instructions, and complied with them more understandingly. There was much more system in their procedure. They searched the entire board first, then they surveyed the total relief layout. This was followed by somewhat more careful inspection of one figure, then of the other, and finally of the parts to be compared. Decisions were quite often rendered before this entire process had been completed, and at other times the latter steps were rehearsed. There were, in contrast with this, all degrees of lack of system.

Conclusions

The only observable difference in the behavior of the seeing and the lifelong blind, under these similar conditions, was in the number of the illusions. Resemblances were many. Here we have evidence enough that observation of the behavior of the blind while perceiving tactokinaesthically under properly controlled conditions is a safe objective procedure in the analysis of human perceiving.

The large number of illusions experienced by the visuals when the stimuli were presented to their sight shows that their inferiority to the blind in active touch perception was due to lack of practice in perceiving.

The older the person, whether blind or a visual, the more illusions he experienced, and the better his school work, the more illusions. These facts indicate that those who are equipped to perceive best are also the most likely to have these misperceptions.

The greater the amount of system in the manner of proceeding in those who were most able to perceive, among both visuals and blind, show that perceiving correctly under the most usual circumstances is an habituated process, and that these habit patterns lead to incorrect perceiving under some of the less usual circumstances. Moreover, the decreasing degrees of success with the less and less capable and less and less systematic ways of going about the perceiving of space relations support the same conclusions. These facts and the tendency to move in straight lines after passing an angle in the ring segments are samples of the evidence that perceptual ability consists, in part, of habits, and that under unusual circumstances these habits lead to misperceptions.

Whatever hinders movement slows the process of perceiving and distorts the patterns or often prevents perception. If the surprise of an interruption is given time to wear off, perception becomes more possible.

Generalizations

The blind and the seeing perceive very much alike even though their sense departments are different. This justifies

the study of perception through the perceptual behavior of the blind.

Habituated systematic procedure in a sensory mode is a requisite to efficient perception.

Perception is necessarily a much more rapid process than apperception, thorough observation. Therefore it relies on mere clues, as has been shown by the results of this research.

The importance of a technique in perception experiments that avoids misleading suggestions lies in the fact that these clues also are mere suggestions that lead aright in most cases.

When these clues are accompaniments of usual shapes and dimensions true perceptions result; but when unusual shapes or sizes possess the clues that are found in usual shapes or sizes, perception habits lead to misperceptions.

Adjacent sides of two figures are shown in this research to serve as simple phases by which their relative sizes are perceived or misperceived. On the other hand, there are evidences that areas, hinted at by combinations of lines, participate in the perception or misperception of the lengths of lines and also of the sizes of other figures. The whole layout seems thus to have a part in the perception of each portion of it.

Perhaps this is the explanation also of the fact that efficiency of perception was greater the more the observer was inclined to explore the whole layout first, then to handle the largest units into which it was readily separated, and to proceed to find details.

The sources of these well established habits of perceiving are partly disclosed in the comparative lack of efficiency of the seeing subjects in active touch perception, and in the greater difficulty in perceiving the more the movements are obstructed, and in the fact that the more capable and the older perceived best. They can therefore be more than hypothetically accounted for in the following ways:

(*a*) Efficiency in perceiving is the result of long intelligent habit-forming experience.

(*b*) Oculo-motor theories cannot explain the perceptions and mis-perceptions of the lifelong blind and they are not

sufficient to account for all these phenomena in observers who see. If vertical lines seem longer than their horizontal counterparts because of some ocular limitation or other in the narrower vertical range, why do persons who have never been able to see have this type of illusion?

(*c*) Whether or not a person's space world has its first foundations laid by movements through environment, as suggested by these results and by observations of infants, much of our knowledge of distances is gained by traversing them.

(*d*) Enough more energy is consumed in climbing hills, stairways, ladders, and trees than by walking horizontal distances, that are equal in terms of the meter stick, to give exaggerated impressions of heights over other dimensions.

(*e*) Hindrances to travelling and other movements are common, and require enough more effort to make all broken distances appear to be longer than unbroken distances that are equal in terms of feet and inches.

Perceiving of areas and distances seems from this research to be dependent on habituated clues and past experiences of energy consumption. But of course these conclusions are far from final.

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